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Research Article

THE CARDIAC OUTPUT IN PATIENTS WITH CIRRHOSIS OF THE LIVER AND TENSE ASCITES WITH OBSERVATIONS ON THE EFFECT OF PARACENTESIS

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Previous studies in this laboratory (1) have indicated that the cardiac output may be elevated in patients with Laënnec's cirrhosis. The question arose as to what role distention of the abdomen by ascites might play in determining the level of systemic blood flow. In the previously reported patients, elevation of cardiac output did not appear to be related to the presence or degree of ascites, but this aspect of the problem required further investigation.

Few studies of the effect of ascites on cardiac output in man have come to our attention. Resnik, Friedman, and Harrison (2) estimated cardiac output in patients with congestive heart failure by means of the acetylene method and noted slight decreases during the accumulation of ascites in four patients. Six hours after paracentesis, performed in one subject, the cardiac output fell from 2.1 liters per min. to 1.6 liters per min.; on the following day it was 1.8 liters per min. Inasmuch as the oxygen consumption decreased proportionately, the arterio-venous oxygen difference remained essentially unchanged. Sherlock (3) studied two patients with tense ascites by means of cardiac catheterization and found that intraperitoneal, intrapleural and right auricular pressures rose after intraperitoneal infusion of saline solution and fell after paracentesis, but the cardiac output remained unaffected.

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CASE MATERIAL AND PLAN OF STUDY

Thirteen hospitalized patients with Laënnec's cirrhosis and tense abdominal ascites were studied. All gave a history of excessive consumption of alcoholic beverages. History, physical examination, fluoroscopy of the chest, and electrocardiogram were obtained in all patients and revealed no evidence of organic heart or lung disease. Studies were made in the fasting state, at rest in recum-

TABLE I

Pertinent data of patients with Laënnec's cirrhosis not previously reported

Case No.	Age and sex	Weight* *lbs.*	Body† surface area m^2	Cardiac output *L./min.*	O_2 cons. *cc. STPD*	Heart rate
			Cirrhosis with tense ascites			
23	44 M	160	1.85	9.14	358	122
24	41 M	257	2.34	10.67	377	106
25	51 F	170	1.84	9.70, 11.33 } 10.52‡	327, 329 } 328‡	120
26	46 M	178	1.95	8.45	240	87
			Cirrhosis without ascites or edema			
27	42 M	185	2.00	9.16	371	74
28	41 M	168	1.95	15.05	320	95
29	52 M	158	1.81	6.74	296	70
30	44 F	128	1.63	5.93	232	75
31	57 M	176	1.90	6.70	267	92
32	39 F	107	1.50	5.39, 5.39 } 5.39‡	296, 304 } 300‡	110

* Actual weight ("wet").
† On basis of actual weight.
‡ Mean of two determinations.

TABLE II

Circulatory measurements before and after paracentesis

Study No.	Case No.	Age	Sex	Body* surface area	Weight	Ascites 0–4+	Periph. edema 0–4+	Time of study	Ascitic fluid removed	Heart rate	Resp. rate	Minute vent. STPD	Oxygen consump. STPD	Cardiac output	Stroke volume	Brachial arterial pressure		Calculated peripheral resistance	Hematocrit
																Phasic	Mean		
				m²	*lb.*				*L.*				*cc./min.*	*L./min.*	*cc.*	*mm. Hg*		*Dynes-cm.⁻⁵ sec.*	%
1.	22	62	M	1.91	216	4+	2+	24 h A†		93	—	—	—	6.64	71	160/95	117	1410	31
					186	0	0	24 h P	10+	94	—	—	—	6.85	73	—	—	—	33
2.	33	46	M	1.65	149	4+	1+	2 h A		98	18	7.06	246	7.82	80	124/78	88	900	35
					121	0	1+	50 min. P	13	105	20	6.91	212	6.72	60	110/21	78	930	30
3.	34	59	M	1.68	152	4+	0	48 h A		94	23	7.39	332	10.7	114	111/69	88	658	40
					134	0	0	2 h P	10	88	—	—	—	17.4	196	134/88	99	456	37
					134	0	0	3 h P		86	17	5.13	270	8.55	100	—	—	—	38
4.	35	59	M	1.73	175	4+	1+	90 min. A		81	—	6.68	241	6.86	85	134/74	92	1070	24
					161	1+	1+	30 min. P	7.5	74	—	—	—	7.25	98	122/62	82	905	24
					161	1+	1+	50 min. P		74	—	5.90	235	7.25	98	—	—	—	23
					161	1+	0	7 d P		74	—	6.16	234	7.60	100	130/66	91	960	21
5. a	36	41	M	1.76	185	3+	1+	3 mos. A		108	19	9.40	346	11.2	104	132/64	80	571	26
					213	4+	4+	1 h A		127	23	7.92	326	12.6	99	104/54	68	431	30
					185	0	4+	40 min. P	12	116	25	7.93	306	17.3	149	104/50	68	314	30
5. b					190	4+	2+	7 d P 1 h A		117	13	5.88	246	10.85	93	110/56	72	399	30
					156	0	2+	30 min. P	10	121	18	6.58	258	12.33	102	96/48	58	282	31
					172	2+	1+	8 d P		112	17	6.70	264	10.63	95	96/50	58	327	29

* Body surface area on basis of weight after paracentesis. † A = Before paracentesis; P = After paracentesis; xxxxxxxxxxx designates paracentesis.

TABLE III

Comparison of the cardiac output in cirrhosis with tense ascites and without ascites

Expression of blood flow	Tense ascites Mean ± S.D.	No ascites Mean ± S.D.	Difference of means / S.E. difference
Cardiac output *L./min.*	10.15 ± 4.60 (13)†	7.73 ± 2.88 (17)	$\frac{2.42}{1.42} = 1.70$
Cardiac index *L./min./M²* *	5.26 ± 1.99 (13)	4.36 ± 1.30 (17)	$\frac{0.90}{0.63} = 1.42$
Cardiac output *cc./cm. height*	60.3 ± 26.0 (13)	45.0 ± 15.4 (17)	$\frac{15.3}{8.13} = 1.88$
Cardiac output, *L./min.* × *100* / cc. oxygen consumption/min.	3.27 ± 0.51 (11)	2.81 ± 0.89 (15)	$\frac{0.46}{0.28} = 1.64$

* Body surface estimation based on "wet" weight. Mean Cardiac Index of 24 normal subjects: 3.60 ± 0.62, L./min./M² (5).

† ( ) = Number of patients.

bency. Five of the 13 patients with tense ascites were studied on six occasions before paracentesis and again at varying intervals after paracentesis. Full hemodynamic data are not reported here on the eight patients with tense ascites who were not followed through paracentesis, since only the values of cardiac output are germane to our discussion. The complete data on four of these eight patients, however, have been reported previously (1).[3] The mean cardiac output of this group of 13 patients with tense ascites was compared to that of a group of 17 patients with Laënnec's cirrhosis without evidence of ascites and/or edema, otherwise comparable, studied in identical manner. Full data on 11 of these 17 "dry" cases have been presented previously (1).[4] Pertinent data on all patients not previously reported are presented in Tables I and II.

METHODS

The *cardiac output* was determined by the dye-injection method as described by other investigators (4) with minor modifications (1). Five milligrams of Evans blue dye were injected into an antecubital vein, and samples of arterial blood were collected from the contralateral brachial artery. This method, in our hands, yields reproducible results. Values of cardiac output in normal subjects agree with accepted standards (1, 5).

The *oxygen consumption* in general was determined over a 3-minute period by the open-circuit method, the cardiac output being determined during the second minute. Expired air was collected in a Douglas bag and the volume measured in a Tissot spirometer. The concentration of oxygen was measured by means of a Pauling oxygen analyzer.[5] The carbon dioxide was not measured. The average R.Q. correction of other investigators (6) was used for converting expired volume to inspired volume. In two instances oxygen consumption was measured over a 6-minute period by means of a closed-circuit water spirometer filled with oxygen, after the determination of the cardiac output (study No. 3, Table II).

Phasic and mean *arterial pressures* were measured directly by means of an electromanometer[6] and recorded on a direct writing oscillograph.[6]

RESULTS

I. *The cardiac output at rest*

The data not previously reported are given in Tables I and II; a comparison of the means is presented in Table III. The mean resting cardiac output in the 13 subjects with tense ascites was 10.15 liters per min., with a standard deviation of ± 4.50, the sample ranging from 6.64 liters per min. to 24.2 liters per min. Seventeen patients without ascites had a mean cardiac output of 7.73 ± 2.88 liters per min. Thus the mean cardiac output in the presence of tense ascites was greater than in the control group without ascites, but this difference in means was found not to be significant statistically, nor was there any significant difference when the comparison between the group with ascites and the group without ascites was made on the basis of body surface area, the values for the cardiac index being 5.26 ± 1.99 liters per min. per M² and 4.36 ± 1.30 liters per min. per M², respectively (Table III). The mean cardiac index of 24 nor-

[3] In the cited reference these subjects were Nos. 15, 17, 19, and 20.

[4] These subjects were Nos. 4–14 in the paper cited.

[5] A. O. Beckman, Inc., Pasadena, California.

[6] Sanborn Company, Cambridge, Massachusetts.

mal subjects studied in this laboratory under comparable conditions (5) was 3.60 liters per min. per M^2 with a standard deviation of $\pm$ 0.62 liters per min. per M^2.

The presence of ascites will increase the estimate of body surface area from height and weight, hence the cardiac index calculated on the basis of "wet" weight (as done here) is probably not comparable to the cardiac index of normal subjects or patients without fluid retention. Therefore, comparisons of cardiac output between the two groups were also made on the basis of height (cc. of blood flow per minute/height in cm.) and oxygen consumption (liters of blood flow per minute $\times$ 100/cc. oxygen consumption per minute). The mean cardiac output, irrespective of the expression used, was higher in the group of patients with tense ascites, but none of the differences were statistically significant (Table III).

Thus the cardiac output in cirrhotic subjects with tense ascites was often elevated, at times normal, but never absolutely low, and in this sample did not differ significantly from that in cirrhotic subjects without ascites.

II. *The response to paracentesis* (Table II, Figure 3)

There were five instances in which studies were performed within three hours or less after paracentesis. In three of these studies, Nos. 2, 4, and 5b, the cardiac output did not change appreciably immediately after paracentesis. In study No. 3 the cardiac output rose from 10.7 liters per min. to 17.4 liters per min. two hours after paracentesis, at which time the oxygen consumption unfortunately was not measured. One hour later the cardiac output had fallen below the original level to 8.5 liters per min., in keeping with a comparable fall in oxygen consumption. In study No. 5a the cardiac output rose from 12.6 liters per min. to 17.3 liters per min. without appreciable change in oxygen consumption.

In four instances the cardiac output was measured one or more days after paracentesis. At no time was it found to differ appreciably from that existing prior to paracentesis. In two of these four studies, Nos. 5a and 5b, the individual was reaccumulating ascitic fluid as judged by an increase in weight of five pounds and six pounds, respectively.

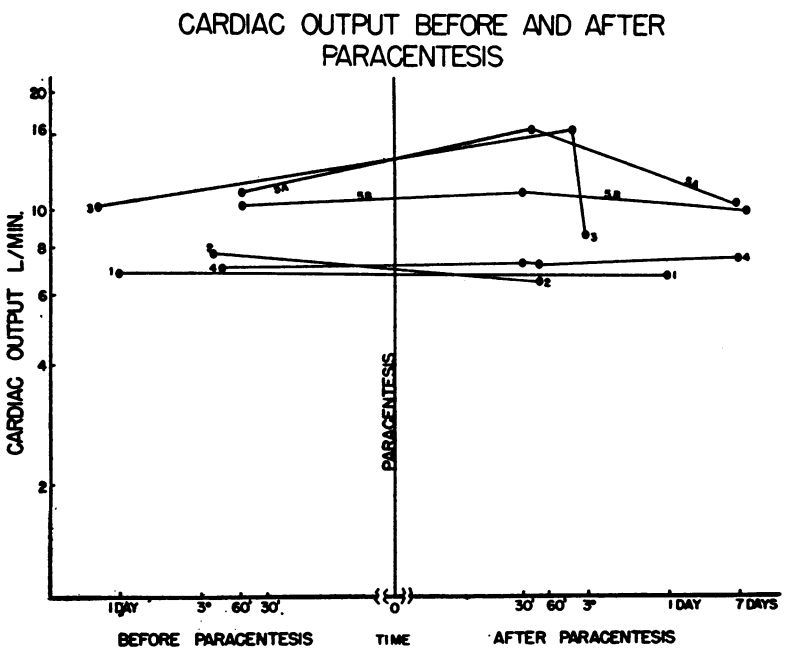

FIGURE 1

Logarithmic scales are used on the ordinate to facilitate comparison of relative changes at different levels of cardiac output, and on the abscissa for convenience.

Changes in heart rate, blood pressure, peripheral resistance, oxygen consumption and hematocrit were somewhat variable and showed no consistent trend.

DISCUSSION

The results obtained in the new cases confirm the previous findings (1): the cardiac output is often elevated in patients with Laënnec's cirrhosis, with or without ascites. A discussion of the possible causes of the high cardiac output state was presented in a previous report to which the reader is referred (1).

The data presented fail to support the thesis that tense abdominal ascites impairs venous return to the heart and thus compromises cardiac output (7). A low cardiac output was not found in any instance and high outputs were observed in a number of patients with marked ascites. These observations were made at rest and in recumbency and do not exclude the possibility that venous return might be affected during exercise. It is also conceivable that with greater degrees of abdominal distention venous return might be impaired. However, it is our opinion that patients sicker than the present group could be studied only with great difficulty and uncertainty as to the achievement of a steady state.

Since Sherlock (3) has shown that in the presence of tense ascites right auricular pressure may be increased, the question arises whether tense ascites *per se* may be a factor in producing a high cardiac output at rest. The increase in auricular pressure, however, appears to be secondary to an increase in intrathoracic pressure which in turn is effected by an increase in intraperitoneal pressure. Inasmuch as the relative right auricular pressure (referred to as intrathoracic pressure) probably remains unchanged, increased venous return is not likely. Indeed, in no instance was a true fall in cardiac output observed after paracentesis.

With two exceptions the level of cardiac output was not appreciably changed after relief of abdominal distention. The cause of the elevation of cardiac output early after paracentesis in studies Nos. 34 and 36a is not obvious. Neither patient showed overt emotional disturbance, and both denied feeling nervous or tense. In both instances subsequent determinations showed lower values. Technical errors cannot be entirely ruled out.

Shifts in body water and extracellular fluid after paracentesis might affect the level of cardiac output. Ascitic fluid forms when forces favoring the passage of extracellular fluid across the capillary walls exceed those favoring its return. The cirrhotic subject with tense ascites is at or approaching equilibrium at a new pressure relationship. The sudden removal of ascitic fluid restores the transcapillary gradient in favor of the passage of water into the peritoneal cavity, and as a consequence extracellular fluid may become "trapped" in the peritoneal cavity (8). Plasma volume may decrease since hemoconcentration has been noted after paracentesis (9). Inasmuch as a decrease in plasma volume, under certain conditions, is thought to decrease the cardiac output (10, 11), it is of interest that the present measurements of cardiac output revealed no appreciable decrease after paracentesis. Moreover, no consistent increase in hematocrit was seen.

All patients with tense ascites had dyspnea on moderate to mild exertion and several felt dyspneic at rest. Paracentesis promptly relieved such dyspnea. From the present investigation it appears unlikely that the level of cardiac output plays an important role in the dyspnea of noncardiac patients with tense ascites, at least not in the resting state.

SUMMARY AND CONCLUSIONS

The cardiac output in 13 patients with Laënnec's cirrhosis and *tense ascites* was compared with that in 17 patients with Laënnec's cirrhosis and *no ascites* in terms of absolute values, and as related to body surface area, height, and oxygen consumption. Patients with ascites showed higher mean values than patients without ascites, but the differences were not significant.

In both groups of patients the cardiac output was often high, sometimes normal, but never low.

Five patients were studied at varying intervals before and after abdominal paracentesis. In general, the resting cardiac output remained essentially unchanged. On two occasions a rise in cardiac output was noted immediately after paracentesis, but subsequent studies showed a return to control values. In no instance did the cardiac output decrease after paracentesis.

It is concluded that the presence of tense ascites

is not an important determinant of the level of cardiac output in patients with cirrhosis at rest and in recumbency.

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