Myocardial Function in Acute Pancreatitis

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Fifteen patients with acute pancreatitis had 68 physiologic cardiopulmonary assessments performed, and they were compared with 61 performed on normal postoperative patients, and 113 on 41 cirrhotics. It was found that the patients with pancreatitis have an elevated cardiac index (CI), which is not due to the hyperdynamic hemodynamic state found in cirrhotics. In spite of this, the Sarnoff curves demonstrated that pancreatitis was accompanied by a myocardial depression $p < 0.03$, not found in hyperdynamic cirrhotics. Cirrhotics are unable to increase their oxygen consumption in response to an increase in CI, as do normal patients or those with acute pancreatitis. In cirrhotics the hemodynamic lesion occurs at the capillary level with the opening of arteriovenous shunts which rob the tissues of their nutritive blood supply, while the patient with acute pancreatitis has a primary myocardial depression and his peripheral vasculature reacts like that of a normal person.

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A MYOCARDIAL DEPRESSANT FACTOR found in circulatory shock[1-4] has been shown to occur in experimental hemorrhagic pancreatitis[5] and in two patients with pancreatitis.[6]

Myocardial depression had not been demonstrated in humans until ventricular function curves of patients with acute hemorrhagic pancreatitis were analysed and found to be significantly depressed.[7] The investigation of ventricular function in these patients is difficult, since many of the patients are cirrhotics who have the hyperdynamic hemodynamic state. Physiologic assessments are, therefore, subjected to a number of variables which have to be defined before conclusions may be reached. Data not only on hemorrhagic pancreatitis, but also on all types of pancreatitis, are analysed here and compared to cirrhotics and normal postoperative patients with special attention to the demonstration of myocardial depression.

Materials and Methods

Fifteen patients with acute pancreatitis, ages from 22 to 73 years, (mean: 36.9 ± 13.1) on whom the diagnosis was made at laparotomy, autopsy examination, or by an elevated serum amylase and the classical clinical picture, were resuscitated by the administration of appropriate intravenous fluids to maintain an adequate urine output. The maximum serum amylase level for each patient ranged from 170 to 12,800 IU (mean 1528.7 ± 3183.3 Dupont ACA method, normal 5-81 IU). Of these 15 patients, ten had hemorrhagic pancreatitis, as proved by celiotomy or needle aspiration biopsy of amylase-rich hemorrhagic ascites, and two of these subsequently developed abdominal abscesses (Table 1).

Physiologic profile studies were carried out on 68 occasions in all 15 patients. A Swan-Ganz flow directed balloon tipped thermodilution catheter (model 93A-131 7F, Edwards Laboratories) was inserted percutaneously through the subclavian or internal jugular vein, using the Seldinger technique, and the position of the catheter tip was monitored on an oscilloscope (model type 2, Pressure module, Datascope), using transducers (model MSD 10-E, Ailtech). The right atrial pressure was also recorded during the procedure with a recorder (model 720 Physiological recorder, Datascope). The tip of the catheter was then advanced into the pulmonary artery. Cardiac output studies were performed by the thermodilution technique, using a cardiac output computer (model 9510, Edwards Laboratories). The following data was collected: height (H), body weight (W), body temperature, cardiac output, peripheral arterial pressure (BP), mean pulmonary arterial pressure ($\overline{PA}$), pulmonary capillary wedge pressure (PWP), right atrial pressure (CVP), per cent oxygen concentration of inspiratory air (FI_{O_2}), hemoglobin concentration, blood gases of pulmonary artery (mixed venous) and peripheral artery, including pH, P_{CO_2}, P_{O_2}, per cent saturation of oxygen, bicarbonate level and base excess. These gas determinations were carried out on a Corning No. 175 automatic blood gas/pH meter.

These data were fed into a programmable calculator

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TABLE 1. *Case Summaries of 15 Patients with Acute Pancreatitis*

Patient	Age	Sex	Serum Amylase Maximum	Pancreatitis	Liver	Mortality
1	36	M	12,800	hemorrhagic	cirrhosis	died
2	27	M	1,240	edematous	cirrhosis	
3	73	F	2,200	hemorrhagic		died
4	37	M	171	hemorrhagic	cirrhosis	died
5	22	M	1,900	abscess		died
6	36	F	159	edematous		
7	25	M	487	edematous	cirrhosis	
8	35	F	500	hemorrhagic		
9	34	F	357	edematous		
10	28	F	706	hemorrhagic	cirrhosis	
11	55	M	180	abscess	cirrhosis	
12	34	M	170	hemorrhagic		died
13	47	M	285	hemorrhagic		
14	38	M	565	hemorrhagic		
15	27	M	1,210	edematous		
	36.9 + 13.1		1528.7 + 3183.3		6/15 (40%)	5/15 (33%)

(model TI-59, Texas Instruments) and calculation was done by an 879 step program with nine memory registers. A printer (model PC-100-C, Texas Instrument) reproduced the cardiopulmonary variables with a graphic format within a minute. The variables calculated were: body surface area (BSA), cardiac index (CI), stroke index (SI), left ventricular stroke work (LVSW), peripheral resistance (TPR), pulmonary vascular resistance (PVR), arteriovenous oxygen content difference (AV diff), oxygen consumption (Qo_2). The formulae used in the calculation of the variables were as follows:

$$BSA = (71.84 \cdot (0.4536 \cdot W)^{0.425} \cdot (2.54.H)^{0.725}) \cdot 10^{-4}\ M^2$$

$$CI = \text{Cardiac output/BSA L/min/M}^2$$

$$SI = 1000 \cdot CI/\text{pulse ml/M}^2$$

$$LVSW = 0.01355 \cdot \text{mean BP} \cdot SI\ g \cdot M/M^2$$

$$RVSW = 0.01355 \cdot \overline{PA} \cdot SI\ g \cdot M/M^2$$

$$TPR = 79.9 \cdot (\text{mean:BP} - CVP)/CI\ \text{dyne} \cdot \text{sec} \cdot M^2/\text{cm}^5$$

$$PVR = 79.7 \cdot (\overline{PA} - PWP)/CI\ \text{dyne} \cdot \text{sec} \cdot M^2/\text{cm}^5$$

$$AV\ diff = C_a - C_v\ \text{ml/dl}$$

C_a: the sum of the hemoglobin-bound and plasma dissolved oxygen content in the arterial blood ml/dl

C_v: the sum of the hemoglobin-bound and plasma dissolved oxygen content in the mixed venous blood ml/dl

$$Qo_2 = 10 \cdot (AV\ diff) \cdot CI\ \text{ml/min/M}^2$$

TABLE 2. *Comparison of Various Physiologic Parameters of Patients with Pancreatitis against Normal*

Parameter	Acute Pancreatitis Mean ± SD n = 68	Normal Patients* Mean ± SD n = 17	Significance of Difference
Mean arterial blood pressure (mm Hg)	95.6 ± 20.9	89 ± 11	$p < 0.05$
Cardiac Index (L/min/M²)	3.51 ± 1.32	2.99 ± 0.36	$p < 0.05$
Pulmonary wedge pressure (mm Hg)	10.1 ± 5.42	4.0 ± 2.0	$p < 10^{-8}$
Left ventricular stroke work (g M/M²)	39.5 ± 18.9	48.4 ± 9.5	$p < 0.005$
Total peripheral resistance (dyne sec M²/cm⁵)	2308 ± 1122	2379 ± 403	NS
Pulmonary vascular resistance (dyne sec M²/cm⁵)	272 ± 152	195 ± 48	$p < 0.0005$
Arteriovenous oxygen difference (ml/dl)	4.61 ± 1.64	4.46 ± 0.67	NS
Oxygen consumption (ml/min/M²)	154.5 ± 72.4	119 ± 37	$p < 0.005$

* Data for normal basal patients taken from reference 8.

Intravenous infusions were controlled, according to the urinary output and the level of pulmonary capillary wedge pressure. The variables from the sixty-eight cardiopulmonary assessments were analyzed retrospectively and compared with 61 profiles performed in nonseptic, noncirrhotic postoperative patients without cardiac or pulmonary disease, and 113 profiles performed on cirrhotics without pancreatitis. Data for normal postoperative patients and cirrhotics has been published previously.[8] The comparison consisted of constructing Sarnoff curves, LVSW on the ordinate and PWP on the abscissa. These curves were constructed from all the values of the parameters obtained from all the patients in each group. The mean values of LVSW at 5 mmHg increments were compared by Student's t-tests for significance. Sarnoff's curves constructed for individual patients were not sufficient

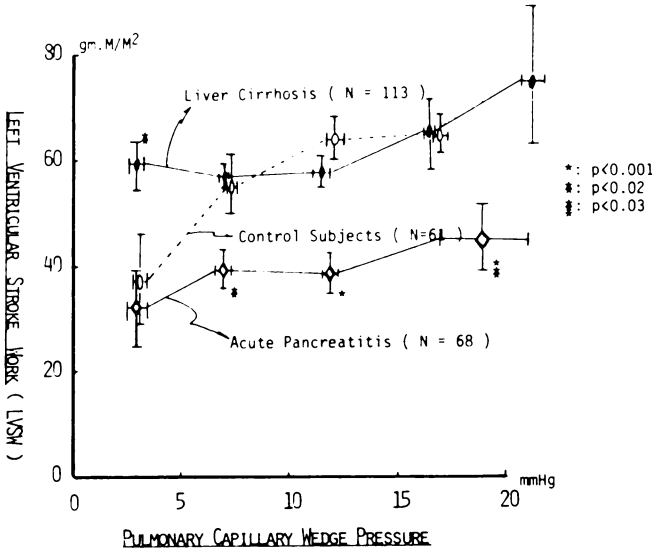

FIG. 1. Ventricular function curves comparing controls, cirrhotics, and patients with acute pancreatitis.

to reach a statistically valid conclusion, but did follow the same pattern when constructed. Also curves were constructed to relate Qo_2 to the CI, in the normal group, cirrhotic group and pancreatitis group, to give us an idea of the adequacy of the cardiac output to maintain tissue metabolism. Significance of differences were obtained with Student's t-test.

Results

The futility of using cardiac index and arterial blood pressure to diagnose myocardial depression is shown in Table 2. CI and BP are increased with $p < 0.05$ in the pancreatitis group, however, LVSW is depressed with $p < 0.005$. That this increase in CI was not due to the hyperdynamic hemodynamic state found in cirrhosis (increased CI, decreased TPR and AV diff) is confirmed by finding no significant differences in TPR or AV diff. An increase in Qo_2 with $p < 0.005$ indicates that these patients tissue metabolism is able to respond to their stressful situation. The increase in PVR ($p < 0.0005$) has been a characteristic finding in acute pancreatitis, and is believed to be related to the high incidence of respiratory failure in these patients.[9] Calculation of correlation between PVR and PWP was attempted and found to be insignificant, showing that the increase in PVR was not due to a failing heart.

Sarnoff curves were plotted for left ventricular function in the patients with acute pancreatitis, and myocardial depression in this group demonstrated with respect to both normal patients and hyperdynamic cirrhotics (Fig. 1 and Table 3). Significance of differences may be noted in Table 3.

The patients with pancreatitis show an ability to increase their Qo_2 along with the CI, just as normal postoperative patients do. Cirrhotics do not have this ability (Table 4, Fig. 2), since their hemodynamic lesion is at the capillary level and not at the cardiac level as the patients with pancreatitis.

Discussion

To demonstrate myocardial depression, a Sarnoff curve[11] has to be constructed and it must be shown that the plot enters the hypodynamic area to a significant degree. This is rather difficult in this situation since patients with acute pancreatitis often suffer from vitamin deficiency, alcoholic cardiomyopathy, hepatic cirrhosis, drug abuse, and acute alcoholic intoxication,[12] all of which can affect the circulatory status. Experimental animals with the hyperdynamic state from the construction of arteriovenous fistulae show normal Sarnoff curves,[13] and yet mild myocardial inadequacy has been shown by tension-velocity curves.[14] In humans the latter method cannot be implemented and alternatives have been devised by analysing the area under dye dilution curves.[15] High cardiac output heart failure may be suspected if the cardiac output is unable to maintain tissue metabolism as evidenced by the variations in Qo_2. Cirrhotics are unable to maintain tissue metabolism as the hyperdynamic state progresses, but this seems to be due to the magnitude of peripheral AV shunt, and not to an inability of the myocardium to respond. This inability to maintain the metabolic needs of the tissues, no matter how much

TABLE 3. *Data for Left Ventricular Function Curves (Fig. 1)*

A. Cirrhotics			B. Pancreatitis				C. Non-Cirrhotic Controls			
Number of Observations	Pulmonary Wedge Pressure Mean ± SD	Left Ventricular Stroke Work Mean ± SD	Significance of Differences in Left Ventricular Stroke Work A vs B	Number of Observations	Pulmonary Wedge Pressure Mean ± SD	Left Ventricular Stroke Work Mean ± SD	Significance of Differences in Left Ventricular Stroke Work B vs C	Number of Observations	Pulmonary Wedge Pressure Mean ± SD	Left Ventricular Stroke Work Mean ± SD
20	3.0 ± 1.1	58.8 ± 21.6	$p < 0.02$	6	3.0 ± 1.3	32.1 ± 18.4	N.S.	8	3.3 ± 0.8	37.0 ± 22.6
40	7.0 ± 1.3	56.8 ± 17.1	$p < 0.02$	29	7.0 ± 1.4	39.6 ± 18.9	$p < 0.02$	18	7.3 ± 1.8	55.0 ± 23.4
35	11.5 ± 1.3	57.4 ± 16.9	$p < 0.001$	23	11.9 ± 1.5	38.9 ± 19.0	$p < 0.001$	22	12.0 ± 1.3	63.9 ± 18.6
13	16.4 ± 1.3	64.9 ± 25.0	$p < 0.03$	10	19.1 ± 6.3	45. 3 ± 19.7	$p < 0.03$	13	16.7 ± 1.6	64.1 ± 13.7
5	21.2 ± 0.8	75.0 ± 30.1								

TABLE 4. *Data Comparing Oxygen Consumption at Different Levels of Cardiac Index (Fig. 2)*

A. Cirrhotics			B. Pancreatitis				C. Non-Cirrhotic Controls			
Number of Observations	Cardiac Index l/min/M² Mean ± SD	Oxygen Consumption ml/min/M² Mean ± SD	Significance of Differences in Oxygen Consumption A vs B	Number of Observations	Cardiac Index l/min/M² Mean ± SD	Oxygen Consumption ml/min/M² Mean ± SD	Significance of Differences in Oxygen Consumption B vs C	Number of Observations	Cardiac Index l/min/M² Mean ± SD	Oxygen Consumption ml/min/M² Mean ± SD
				18	2.5 ± 0.3	114.5 ± 38.4	$p < 0.03$	9	2.7 ± 0.2	147.5 ± 35.4
11	3.5 ± 0.5	103.3 ± 37.0	$p < 0.03$	16	3.5 ± 0.3	158.2 ± 62.1	$p < 0.03$	19	3.5 ± 0.3	202.9 ± 65.3
11	4.5 ± 0.4	160.5 ± 36.3	N.S.	16	4.4 ± 0.4	175.1 ± 80.9	N.S.	14	4.4 ± 0.3	163.3 ± 49.1
9	5.5 ± 0.3	155.9 ± 43.3	$p < 0.02$	8	5.4 ± 0.3	207.0 ± 86.5	N.S.	9	5.3 ± 0.3	235.4 ± 76.1
8	7.2 ± 0.9	157.2 ± 35.0	$p < 0.01$	2	6.7 ± 0.3	297.0 ± 75.0	N.S.	8	7.0 ± 0.7	305.3 ± 130.3

the CI is increased, accounts for their inability to withstand stressful events. This is not the case in our patients with pancreatitis despite the fact that 40% of them were cirrhotics, and it has been shown definitely that their hemodynamic lesion is at the cardiac level. Presumably this occurs because of the presence of a myocardial depressant factor elaborated in the pancreas and shown to be elevated in patients with acute pancreatitis.[6]

Right ventricular data was not presented here because the method used to calculate RVSW in the routine physiologic profile study is inadequate. By this method only the portion of work due to potential or pressure energy is measured, and that due to kinetic energy is not. Right ventricular stroke work has a large component due to kinetic energy because of the relatively low pressure system in which it occurs. It must be taken into account[15] especially in high cardiac output states when it can become about half of the total right ventricular work.

Seven of our patients required respiratory support during their illness, supplying a good sample to study respiratory failure in pancreatitis. No correlation was found between the level of PWP and the PVR. Therefore, the increase in PVR is unrelated to the increase in end diastolic pressure of a failing heart, but due to another mechanism as has been suggested previously.[10,16]

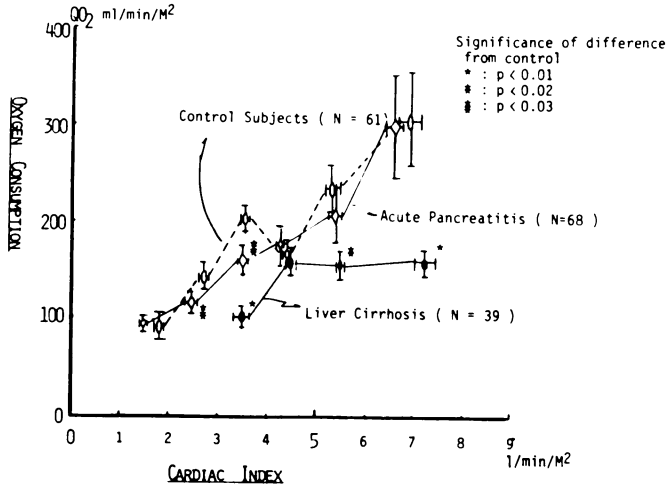

FIG. 2. The relation between the hyperdynamic state as measured by the cardiac output and tissue metabolism as measured by the oxygen consumption. A comparison between controls, cirrhotics, and patients with acute pancreatitis.

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