A Computer Based Index for the Prediction of Operative Survival in Patients with Cirrhosis and Portal Hypertension

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THE PROGNOSIS of portal decompression in patients with cirrhosis and portal hypertension has been shown to be worse in the presence of a hyperdynamic cardiovascular state, similar to that seen in septic shock.[6] This hyperdynamic state is characterized by a decrease in net vascular tone, a diminished peripheral oxygen extraction in the presence of an increased cardiac output, an increase in systemic and pulmonary arteriovenous shunting, and by the presence of myocardial depression. Studies suggest that the ability of a given patient with extensive cirrhotic liver disease to survive major portal decompressive procedures is related to the degree of interaction between abnormal circulatory function and the ability of the myocardium to compensate for these peripheral abnormalities.[6] To develop an index for patient evaluation, assessment-oriented programs have been designed on magnetic tape for use with a relatively inexpensive digital computer, the Programma 101.† These indices enable the location of a given patient's physiologic position in each of the above cardiovascular functions, normalized with regard to mean values for control patients, those in hyperdynamic septic, and nonseptic shock. The present study is based on the evaluation of 44 patients with hepatic cirrhosis and portal hypertension. A survival index has been quantified relating the abnormalities in the peripheral circulation to the level of myocardial capacity. This survival index has enabled preoperative separation of cirrhotic patients into three groups with markedly different probabilities of operative survival.

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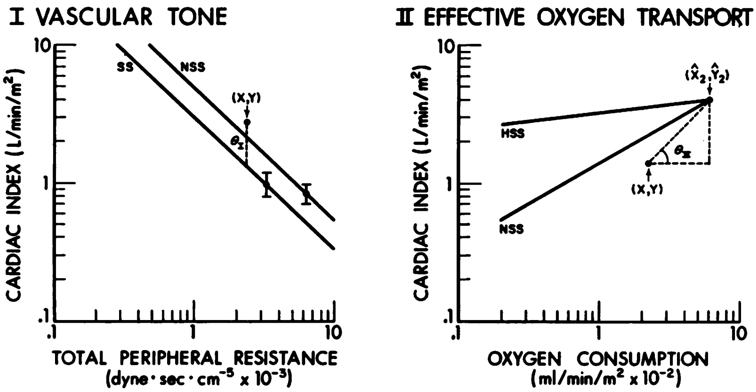
Methods and Materials

Cardiovascular hemodynamics, and oxygen consumption were measured in 44 patients with cirrhosis and portal hypertension who were evaluated preoperatively prior to procedures for portal decompression. The data obtained from these patients were compared with mean values for 30 patients in septic shock, 14 patients in nonseptic shock and 13 patients who had neither shock nor liver disease, but who were studied electively prior to an operative procedure. These patients have been previously reported,[5] and although data on individuals will not be reported again in this paper, mean values derived from previously obtained information will be presented to serve as reference values for the present study. This paper is concerned with statistical and mathematical technics used in developing indices of physiologic correlation suitable for computer evaluation of cardiovascular data obtained from critically ill patients.

All cirrhotic patients whose data were used were studied preoperatively by bedside cardiac catheterization[3] prior to elective or urgent portal decompression. In each patient a 36-inch polyvinyl intrave-



X = TPR
Y = CI
$Y_{NSS} = 4.776\ x^{-0.8979}$
$Y_{SS} = 3.123\ x^{-0.9513}$

FUNCTION INDEX:

$\theta_{I} = \mathrm{Ln}(Y) - [1.1388 - 0.9513\ \mathrm{Ln}(X)]$

(The two curves are essentially parallel; hence the angular displacement becomes simply the distance from one of the curves.)

X = O_2 Con./m^2
Y = CI
$Y_{NSS} = 1.370\ x^{0.6698}$
$Y_{HSS} = 3.791\ x^{0.0458}$

FUNCTION INDEX:

$\theta_{II} = \arctan\left[\frac{\mathrm{Ln}(\hat{Y}_2) - \mathrm{Ln}(Y)}{\mathrm{Ln}(\hat{X}_2) - \mathrm{Ln}(X)}\right]$, where $\hat{X}_2 = 5.7$, $\hat{Y}_2 = 4.1$

FIG. 1. Algorithms for the determination of the unnormalized index of Vascular Tone (I) and Effective Oxygen Transport (II) of a given patient with coordinates (X, Y).

nous catheter was introduced percutaneously into the basilic or external jugular vein, and flow directed into the right atrium using the intracardiac electrocardiogram as the monitor of position. This catheter was used to monitor central venous pressure which was obtained electronically using a Statham P23Db strain gauge. A Teflon catheter was passed percutaneously into the femoral artery, or placed into the radial artery when femoral catheterization was not possible, and was also monitored electronically so as to measure arterial blood pressure. Known quantities of indocyanine green dye were introduced into the central venous catheter and arterial samples were obtained using a constant speed withdrawal pump and electronically recorded with the use of photoelectric densitometer on a photographic oscillograph. Arterial and mixed venous hemoglobin, pH, P_{CO_2}, and oxygen tension values were obtained, the arterial and venous oxygen saturations were calculated. The computations of cardiac output, cardiac index, total peripheral resistance, stroke work, and other cardiovascular parameters were made using a cardiovascular program developed for the Olivetti Programma 101 and previously reported.[8] Similarly, the computation of oxygen consumption, oxygen consumption per square meter, and index of effective oxygen transport were also computed from the primary data by means of an oxygen consumption program developed for use with this portable computer.[8]

Results

Studies of patients in shock have demonstrated that information concerning the status of the peripheral circulation and myocardial function can be described in terms of four physiologic correlates.[5] These correlations were determined experimentally, and are represented by parabolic functions (plotted by convention on a log log scale *), relating two physiologic variables:

1. *Vascular Tone,* relating the cardiac index with total peripheral resistance (Fig. 1).

* Since equal distances measured along a logarithmic scale correspond to equal ratios, the meaning of a parabolic function is that a given per cent increase in one variable corresponds to a specific per cent increase (or decrease if the slope is negative) in the other correlated variable.

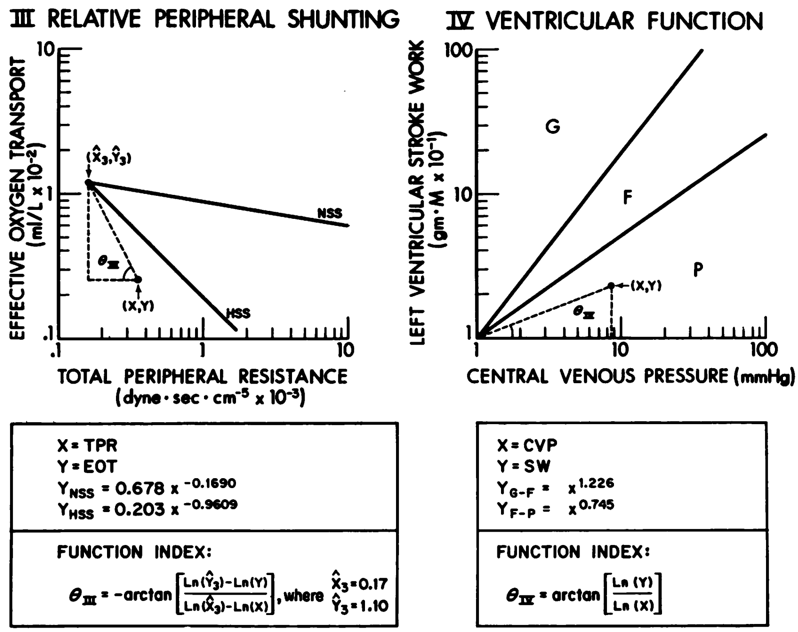


FIG. 2. Algorithm for the determination of the unnormalized index of Relative Peripheral Shunting (III) and Ventricular Function (IV) for a given patient with coordinates (X, Y).

2. *Effective Oxygen Transport,* relating the cardiac index with oxygen consumption per m² (Fig. 1).
3. *Relative Peripheral Shunting,* relating effective oxygen transport with total peripheral resistance (Fig. 2).
4. *Ventricular Function,* relating stroke work with central venous pressure (Fig. 2).

The Determination of Reference Curves of Cardiovascular Function

The fitting of the parabolic curves was carried out using a program for the determination of the parabolic function which also permitted the evaluation of a coefficient of correlation (^{r}Log Y·Log X), and the standard error of estimate of this function (^{s}Log Y·Log X). This program will also permit the updating of data as new points are obtained in order to better define the lines used as mean values in these line fits, and will also allow for the updating of the reference lines used in the normalization program.

The data show pronounced heterogeneity with respect to normal (N), septic (SS), and nonseptic (NSS) states. In the Vascular Tone (VT) function (Fig. 1), for instance, there is complete separation of the septic (SS) and nonseptic (NSS) data points, and the two curves can be fitted with parabolic functions whose regions do not overlap within one standard error of estimate.* Therefore, to develop an index for each correlate, an unweighted least square's fit was performed to determine the parameters of the parabolic function representing 1) septic (SS), and 2) nonseptic (NSS) curves for that correlation. In the indices for Effective Oxygen Transport (EOT) (Fig. 1) and Relative Peripheral Shunting (RPS) (Fig. 2) the heterogeneity lies between the nonseptic shock group and the so-called "hyperdynamic," or high cardiac output, septic shock (HSS) patients in whom the parameter of oxygen consumption fails to keep pace with the demands of the increased hemodynamic

* The standard error of estimate may be looked at as a measure of the dependability of the estimating function (the fitted curve) or as a measure of the dispersion of data points around the fitted curve. Within a region of one standard error of estimate on either side of the fitted curve 68.27% of the points may be expected to fall if the scatter follows a normal distribution.

function. As previously indicated,[5] this "hyperdynamic" group represents a separate clinical entity with a different pattern of physiologic abnormalities and a different clinical prognosis. In the case of the Ventricular Function (VF) index (Fig. 2), the data separation was mainly in degrees of good or bad ventricular function relationship, hence the parabolic functions determined were a Good-Fair line and a Fair-Poor line, dividing the graph into three regions.

mal group. The probability that NSS and SS groups represent different populations is 72.7%.

EOT. There is a high correlation for the NSS data along with a low standard error of estimate. The HSS data, however, have a slope that is nearly horizontal, indicating that there is little effect of the x-variable for these data. The standard error of estimate is very low, however, so the function representing these data can be quite accurately determined. There is a probability of 94.4% that the NSS and HSS lines represent different populations.

RPS. The NSS curve also approaches the horizontal, although the standard error of estimate is low. (In this case a weighted fit, to permit the intersection of NSS and HSS curves to occur at a point greater than all the known data, provided the parameters of the NSS fit as used in the computer program.) The HSS curve has low but significant correlations and an acceptable standard error of estimate. The separation of the two curves (NSS and HSS), however, is marked, with a probability of 67.3% that they represent different populations. In all three indices, Vascular tone, Effective Oxygen Transport, and Relative Peripheral Shunting, the values for the normal patients lay between the extremes delineated by the parabolic functions for the nonseptic shock and septic shock (or hyperdynamic septic shock) groups. Although the spread of normal values was generally wider than in the shock groups, with the consequence being a lower coefficient of correlation (^{r}Log Y · Log X), all of the normal values were contained in the region between the two shock functions and the separations were statistically significant.

Statistics of the Fitting

	Vascular Tone		EOT		RPS	
	NSS	SS	NSS	HSS	NSS	HSS
^{r}Log Y · Log X	−0.956	−0.907	0.829	0.232	0.002	−0.473
^{s}Log Y · Log X	0.065	0.087	0.115	0.059	0.139	0.267
n	14	30	14	9	11	9

Qualitative Aspects

VT. The SS and NSS curves exhibit very high correlations and can be fitted with parabolic functions with low standard errors of estimate. The function fitting these data can be determined with very low standard error of estimate also. From significance studies of these statistics it was found that there is a probability of 99.9% that the NSS curve is different from normal and a probability of 99.6% the SS curve also differs from the normal group.

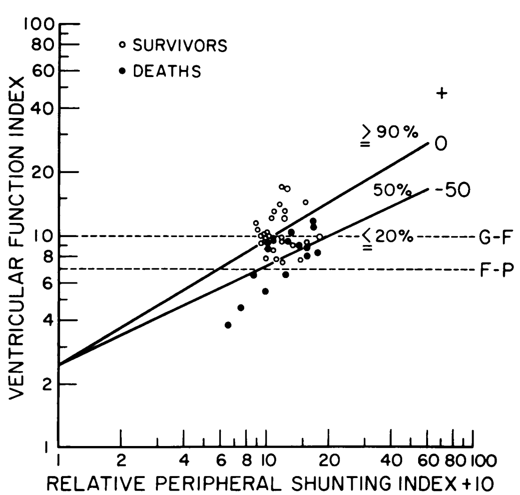


FIG. 3. Survival pattern based on the preoperative determination of the indices of Relative Peripheral Shunting and Ventricular Function in 44 patients with hepatic cirrhosis and portal hypertension prior to portal decompressive surgery.

VF. The curves separating the graph into three regions were done entirely by sight, so as to delineate a Good, Fair, and Poor range of ventricular function based on data which appears to separate the levels of myocardial function in the shock states studied.[5]

Regarding Zero Correlation and Curve Separation

When r = 0, as is the case when a function is parallel to the x-axis, the standard error of estimate becomes the standard deviation of the Y-variable. If the standard error of estimate is low, then the data may be characterized quite accurately as has been done in the EOT and RPS functions since the scatter is small. The curve in such a case is extremely useful if one is interested, as we are here, in the heterogeneity of the data and its separation into groups or separate curves. The function, as a matter of fact, is considerably simplified, since the data is independent of the X-variable.

Construction of Indices of Cardiovascular Function

Once the fits were determined, an angular displacement of a particular point with respect to the fitted lines and their point of intersection was taken to be an unnormalized index for describing the status of that point, as far as that particular function was concerned (Figs. 1, 2). This was considered valid since the data for normal patients, although showing a somewhat wider spread, lay intermediate between the septic and nonseptic curves in the area of Vascular Tone, Effective Oxygen Transport, and Relative Peripheral Shunting, and above the Good-Fair line in the case of the Ventricular Function. By normalizing this angle such that a value of +5.0 or −5.0 represented a point on one of the curves, a convenient measure was obtained for determining deviations from normal toward the septic or nonseptic shock mean reference lines.* The four functions and the index associated with each of them are shown in Figures 1 and 2.

As noted above, the primary indices were normalized in a way to permit quick assessment of the patient's condition. In the table below the critical values of the normalized indices are shown. The entries in the column labeled Septic Shock, Non-Septic Shock, Fair-Poor, and Good-Fair are the normalized values when the specified index lies exactly on the fitted curve indicated. The normal line was arbitrarily set to zero in the VT, EOT, and RPS indices. However, since the coefficients of correlations for the normal patients were lower than corresponding NSS and HSS values, although with a small standard error of estimate, no prejudice is implied about the true slope of the normal curve in a larger population, except that the range of normal data appears to lie between the septic and nonseptic shock functions.

	Septic Shock	Nonseptic Shock	Normal
VT-Index	−5	5	0
	Hyperdynamic Septic Shock		
EOT-Index	−5	5	0
RPS-Index	5	−5	0

	Very Poor	Fair-Poor Line	Fair	Good-Fair Line	Very Good
VF-Index	0 to 7	7	7 to 10	10	10 to 20

Determination of the Survival Index

A study of preoperative patterns of cardiovascular hemodynamics and oxygen consumption for 44 cirrhotic patients with portal hypertension revealed that the probability of survival or death bore a relation to the net cardiovascular functions, as expressed in terms of the four correlation in-

* The necessity of choosing a point of intersection can mean that there are some physiologically realizable values for which no valid index can be computed, since they lie in a mathematically undefined region beyond the intersection of the two curves. This occurs in the EOT index for values of oxygen consumption per square meter of greater than 570 ml./min./m^2. Similarly, in the VF index, because of programming restrictions, values for CVP of 1 mm. Hg or less are by convention entered as 1.36 mm. Hg.

dices described above. In its simplest form, a net cardiovascular function can be composed by inspecting a plot of the index for the Ventricular Function versus the index for the Relative Peripheral Shunting (Fig. 3). This amounts to a synthesis of all the information in the five physiologic variables used as primary inputs (see below), and of the correlations discovered between them. As in the case of the original functions, the data seemed best treated by a plot of the logarithms. When this was done, a striking pattern was manifested. Two intersecting parabolic functions could be determined which divided the graph into three regions, an analogue in terms of chances of survival to the Ventricular Function situation of Good, Fair, and Poor. Indeed, with the data available (Table 1), the regions represent survival percentages of 100%, 47%, and 20%. To express a given point's location on the graph (Fig. 4), a primary (unnormalized) index, equal to the angular displacement of any patient point; with respect to one of the lines and the point of intersection of these functions, was simply normalized such that any positive number represented very good chances (G), any number between 0 and −50 represented approximately a 50% chance (F), and any number less than −50 represented a very remote chance (P) of surviving portal decompressive surgery. In broad terms the physiologic interpretation of this graph is that in order to survive, a patient whose peripheral arteriovenous shunting is low does not need as good a Ventricular Function relationship as one whose peripheral arteriovenous shunting is high.

cardiac index (CI), oxygen consumption per square meter (O_2Con/m^2), central venous pressure (CVP), and stroke work (SW) previously computed from the primary data,[8] and the program outputs the indices of Vascular Tone (VT), Effective Oxygen Transport (EOT), Relative Peripheral Shunting (RPS), Ventricular Function (VF), and the Survival Index.

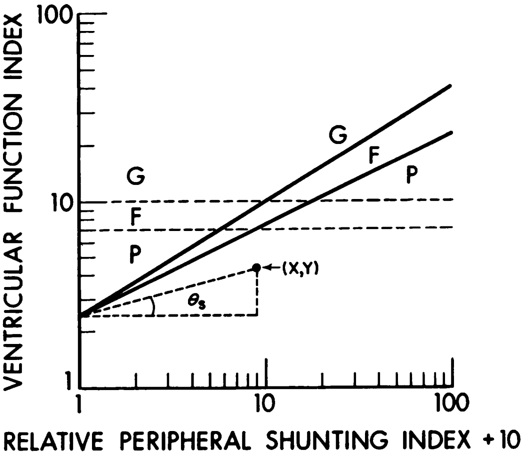
The value in using a continuous function index (Fig. 6) rather than a step function lies not in a seemingly more precise index (the precision is limited by the statistical spread of the data), but in the fact that a trend toward or away from normal circulatory status can be seen on an ongoing basis. These indices were designed to reflect in one number all the relevant information from each graph of the individual physiologic correlate, so that a time-based plot of each function could be obtained (Fig. 7). A simple step function indicating whether a point lay within one standard error of estimate of the septic or nonseptic curves or else intermediate (the region expected of normal patients) between them would suffice to tell with significant accuracy what physiologic condition was to be expected. But a continuous function may be plotted on a time scale so that information regarding the patient's response to stress and therapy may be obtained.

The importance of this kind of prognostic information must be emphasized, since otherwise there was little in the way of distinguishing data to separate the two groups preoperatively. Only one patient in this series fell into Child's[1] class A. This patient had a preoperative Survival Index

	Very Poor	Fair-Poor Line	Fair	Good-Fair Line	Very Good
Survival Index	<−50	−50	−50 to 0	0	any positive number

A sample program output is shown in Figure 5. The physician or surgeon attending the patient enters the values for uncorrected total peripheral resistance (TPR),

of 27 and did well after portal decompressive therapy. All the rest were class B and C. The mean McDermott liver index for the remaining 43 class B and C survivors



X = RPS INDEX + 10
Y = VF INDEX

$Y_{G-F} = 2.51\,X^{0.5821}$

$Y_{F-P} = 2.51\,X^{0.4691}$

SURVIVAL INDEX:

$$\theta_s = \arctan\left[\frac{\mathrm{Ln}(Y) + 1.382}{\mathrm{Ln}(X)}\right]$$

FIG. 4. Algorithm for the determination of the unnormalized Survival Index in a given patient whose coordinates are (X, Y).

was 1.84 SD ± 0.67 and for the deaths 1.90 SD ± 0.41. Both groups had about the same distribution of splenorenal versus portacaval anastomotic procedures. However, nine of the seventeen deaths occurred in patients undergoing urgent portal decompressive procedures. Of these nine, four had survival indices less than −50, but five lay between −46 and −2, and this suggests that the patient who must undergo emergency shunt surgery does not necessarily represent a worse risk than the elective case, although with its high incidence of intraoperative hypotension the stress of an emergency procedure may be greater. However, what was of significance in the patients undergoing emergency portal decompression was the relative decrease in the index of ventricular function in proportion to the degree of abnormality in relative peripheral shunting. This has been commented upon before[6] but is here quantified by the VF and RPS indices. This disproportionate reduction in myocardial capacity strongly suggests that in the patient who must undergo emergency operation, the operative prognosis, reflected by the Survival Index, might be improved by the preoperative use of a cardiac inotropic agent such as a rapid acting digitalis preparation, and by the avoidance of excessive volumes of fluids or blood in the immediate postoperative period when the heart may be most depressed.

Time Series Evaluations

An example of the usefulness of these four time based physiologic functions, and the Survival Index in evaluating the time course of patients with cirrhosis and portal hypertension, is shown in the final figure. As an example, this graph (Fig. 7) shows two patients who were studied extensively preoperatively, intraoperatively, and postoperatively, throughout their total courses. One patient survived portal decompression for more than 2 years and was studied

			V
INPUT	TPR	800	S
	CI	3•8	S
	O_2Con/m^2	60	S
	CVP	6	S
	SW	90	S
			S
OUTPUT	VT-INDEX	-5•40269673	A◊
	EOT-INDEX	-5•17285619	A◊
	RPS-INDEX	5•09604368	A◊
	VF-INDEX	9•80489213	A◊
			S
	SURVIVAL INDEX	-35•00000000	A◊

FIG. 5. Sample program print-out containing the input variables inserted by the physician, and the normalized output indices of Vascular Tone (VT), Effective Oxygen Transport (EOT), Relative Peripheral Shunting (RPS), Ventricular Function (VF), and the Survival Index. Although only the first place to the right of the decimal has any significance in these indices, it is necessary to use 8 decimal places in the print-out in order to avoid round-off errors in the course of the program.

TABLE 1.

Survival Index	Living	Deaths	% Survival
Greater than 0	17	0	100
−0.1 to −50	8	9	47
Less than −50	2	8	20
	—	—	—
	27	17	63

again at that time. The other succumbed on the second postoperative day. This figure presents the relevant physiologic abnormalities and their time course in each patient. Preoperative evaluations of the two patients demonstrated that the patient who succumbed was mildly hyperdynamic with a Cardiac Index of greater than 3 liters/min./m.^{2}, while the surviving patient lay in the normodynamic range.[5] More detailed analysis of the physiologic status of the two patients provided by the various cardiovascular indices discussed in this paper indicated that the nonsurviving patient showed a marked abnormality in the index of Effective Oxygen Transport which was decreased to the level of the mean values found in hyperdynamic septic shock. This patient also demonstrated an increase in the index of Relative Peripheral Shunting to a level greater than the mean value for patients with hyperdynamic septic shock, indicating a major degree of abnormality in the peripheral circulation. There was also a decrease in the Ventricular Function

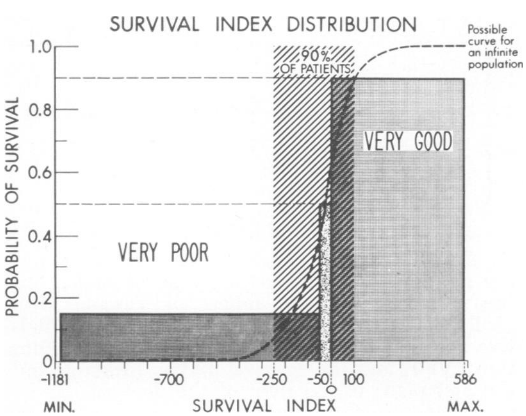


FIG. 6. The Survival Index distribution as a function of the probability of survival.

Index, which although minimal when compared with the level of the surviving patient, nevertheless remained consistently reduced throughout the entire clinical course. The Survival Index, however, revealed that a marked separation existed between the two patients. The patient who lived had a preoperative Survival Index of 14 placing him in the greater than 90% survival region, but the patient who died following operation had a preoperative Survival Index of −51 which placed this individual in a statistical region where less than 20% of the patients studied survived beyond the immediate postoperative period. In both patients the response of the Survival Index to operation was similar in direction, but the separation between them was maintained throughout. Both patients responded to operation by increase in the Vascular Tone Index above baseline levels indicating a vasoconstrictor response to the stress of operation. During the operative period when blood loss occurred, there was a tendency for the index of Relative Peripheral Shunting to decrease toward the mean nonseptic shock value. But, the nonsurviving patient was not able to increase the Effective Oxygen Transport Index in response to the operative stress to the level present in the patient who lived. In both cases, however, there was a significant decrease in the Ventricular Function Index during operation. The Survival Index also showed a marked decrease in both patients early in the operative period with a tendency toward compensation near the close of the operative procedure. There was a marked overshoot in the Survival Index to an improved value during extubation, when a marked reflex sympathetic stimulus appears to be present.[2] The surviving patient also responded to this sympathetic stimulus by a transient increase in the cardiac index. But in the nonsurviving patient there was a fall in cardiac index in spite of the stimulation of extubation, and this was accompanied by an actual decrease in

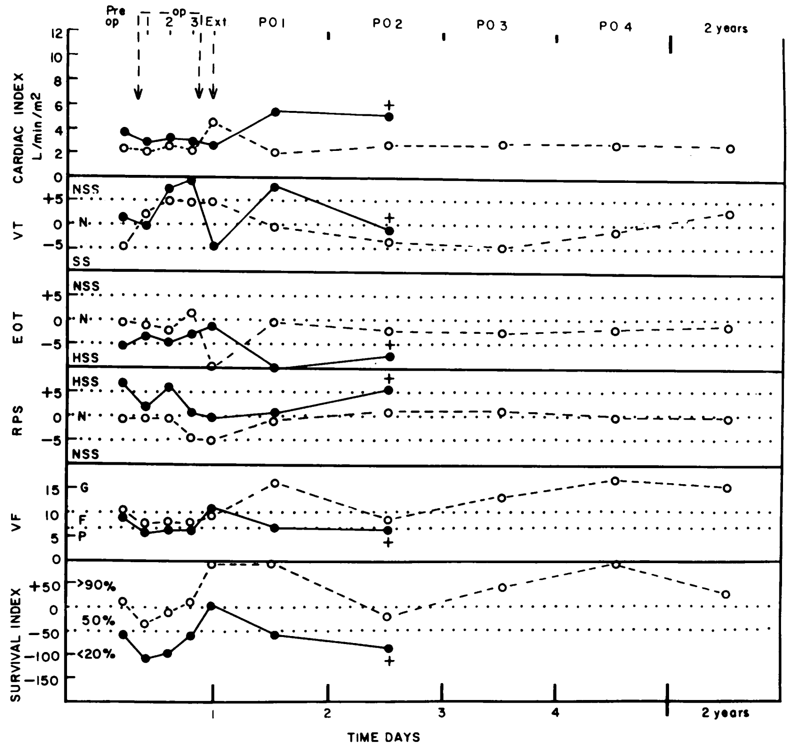


FIG. 7. Time-series evaluation of the various normalized cardiovascular indices in two patients with cirrhosis and portal hypertension. The surviving patient is indicated by the open circles, and the patient who succumbed by the closed circles. Preoperative values are shown as well as three intraoperative values (1, 2, 3), and the time of operative extubation (EXT). Values taken on the first, second, third and fourth postoperative days are shown as well as the late follow up of 2 years on the surviving patient.

the Vascular Tone Index. Both patients tended to have an increase in the Ventricular Function Index during extubation and both showed an increase in the overall Survival Index. However, in the nonsurviving patient it only barely entered the range of positive values. This suggests that the sympathetic response to extubation includes a significant cardiac inotropic component, but that the nonsurviving patient had a reduced ability for peripheral vascular response. On the first postoperative day the most marked separation in the pattern of physiologic response occurred. The nonsurviving patient had a marked increase in Cardiac Index and became significantly more hyperdynamic than preoperatively. This hyperdynamic state was maintained until death. It occurred in spite of a marked increase in the Vascular Tone Index and was accompanied by a major decrease in the efficiency of oxygen extraction. Although in the nonsurviving patient, the Relative Peripheral Shunting Index declined relative to the preoperative value during the postoperative period, it was always greater at any time than that present in the surviving patient and it continued to increase until the time of the patient's demise. This suggests that the peripheral abnormalities reflected by the hyperdynamic state represent a major factor in the circulatory decompensation seen in hyperdynamic disease of the liver.

The most significant difference in response between these patients was seen in the Ventricular Function Index. The surviving patient demonstrated a marked increase in ventricular function on the first postoperative day. This myocardial overshoot is a characteristic feature in nearly all patients who survive major operations regardless of whether they have liver disease or not, and its absence in the nonsurviving patient can only be taken as a very poor prognostic sign. The Survival Index in the surviving patient also shows the effects of what must be an adrenergic response in the postoperative period by a persistent elevation to values greater than normal.

The nonsurviving patient on the other hand had a progressive worsening of the Survival Index to a level where the statistical prognosis for survival in previously studied cases has been less than 20%.

Discussion

The need to quantify the abnormalities seen in cirrhotic hepatic disease so that clinical impressions can be critically examined is essential before meaningful evaluations of the effects of medical and surgical intervention can be assessed. The present study is an attempt to apply computer technics to permit the alterations in the physiologic responses of the cirrhotic to be quantified with reference to the range of known human responses. The development of these normalized cardiovascular function indices also permits the interaction of the various component responses to be serially evaluated in something approaching real time. The use of these time-based indices also permits online determinations of an individual patient's response to therapy to be made which can provide information of major prognostic significance before obvious clinical changes occur.

Del Guercio and his colleagues [2] previously noted that patients who do poorly after portal decompression procedures often manifest a hyperdynamic state with persistent elevation in the Cardiac Index. Siegel *et al.*[6] recently showed that this hyperdynamic state is characterized by a decrease in vascular tone, a persistent abnormality in the efficiency of oxygen extraction, and an increase in the relative degree of peripheral arteriovenous shunting. Their studies also suggest that the degree of increase possible in ventricular function is a major factor in permitting the hyperdynamic patient to compensate for the abnormalities in his peripheral circulation. Both the surviving and nonsurviving patients shown as examples in this paper had declines in their Ventricular Function Index on the second postoperative day and this was characteristic of nearly all patients studied. Reduction in ventricular function tends to occur at a time when the level of peripheral vascular abnormalities is increasing toward the level seen in hyperdynamic septic shock and is usually accompanied by a fall in the Survival Index. This suggests that the second postoperative day may be a critical one for the borderline patient and that the surgeon should be especially vigilant at this time. In fact, nearly one half the postoperative deaths in patients studied occurred between the first and third day. As most surviving patients recover from portal decompression there is an increase in both the Ventricular Function Index and the Survival Index in the third and fourth postoperative days. This is usually accompanied by a tendency in both the Effective Oxygen Transport Index and in the Index of Relative Peripheral Shunting, to return toward normal, and suggests a return of peripheral vascular function to control values. Although most patients studied in long term follow up after portal decompression for cirrhosis show a deterioration in the circulatory correlates of hepatic function,[4] this is not always true, and the patient presented shows there may be a tendency for stabilization, and in some instances, improvement in all hemodynamic parameters, provided the patient does not persist in a continuing hepatic insult after portal decompression.

Although the use of the Survival Index has permitted the prediction of operative prognosis better than any other currently used index of liver function or system of classification of the status of hepatic dysfunction, it is important to emphasize what the Survival Index is, and what it is not. It is merely a numeric value expressing the *statistical* probability of survival based on an integrated estimate of cardiovascular function in a relatively small population sample. It is not a sentence of death, or a license for *carte blanche* in the therapy of any individual patient, but merely an indication of the patient's ability to compensate for a major physiologic stress, compared to previously studied patients. Its purpose is not to substitute for careful patient evaluation, but to provide an additional datum which the surgeon may use in his decision making process. By focusing on the major system responsible for immediate postoperative compensation, and by reducing the time needed to obtain the necessary data, the use of computer technics actually permits the surgeon to spend more time with the patient and to spend this time in a more efficient manner. The data obtained by the use of these assessment-oriented computer programs may also enable the surgeon to come to decisions on a more rational basis, and permit him to tailor therapy to suit the individual on the basis of physiologic considerations.

Summary

The prognosis of portal decompression in patients with cirrhosis and portal hypertension is worse in the presence of a hyperdynamic cardiovascular state, similar to that seen in septic shock. It is characterized by a decrease in net vascular tone, a diminished peripheral oxygen extraction in the presence of an increased cardiac output, an increase in systemic and pulmonary arteriovenous shunting, and myocardial depression. In order to develop an index for patient evaluation, assessment-oriented computer programs have been designed on magnetic tape or use with a relatively inexpensive digital computer. These enable the location of a given patient's physiologic position in each of the above cardiovascular functions, normalized with regard to mean values for control patients, and those in hyperdynamic septic, and nonseptic shock. Based on the recent study of 44 patients with hepatic cirrhosis and portal hypertension, a Survival Index has been quantified relating the abnormalities in the peripheral circulation to the level of myocardial capacity. It has enabled the preoperative separation of cirrhotic patients into three groups whose probability of operative survival was, respectively, >90%, 50%, and <20%. A physiologic interpretation of this index suggests that in cirrhotic patients an increasing abnormality in peripheral arteriovenous shunting requires an increased myocardial capacity in order to permit survival. This index has permitted the discrimination of good from bad operative risks in patients in whom there was no significant difference on the basis of liver function tests. It also provides a way of quantifying a patient's response to therapy as a time based function.

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