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Artículo 113.233

Cardiovascular abnormalities in special conditions of advanced cirrhosis. The circulatory adaptative changes to specific therapeutic procedures for the management of refractory ascites

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ABSTRACT

Advanced liver disease is characterized by decreased arterial blood pressure and peripheral vascular resistances, increased cardiac output and heart rate in the setting of a hyperdynamic circulatory pattern favoured by total blood volume expansion, circulatory overload and overactivity of the endogenous vasoactive systems. Reduced heart responses to stressful conditions such as changes in loading conditions of the heart in presence of further deterioration of liver function such as refractory ascites, hepatorenal syndrome, spontaneous bacterial peritonitis and bleeding esophageal varices have been recently identified and the knowledge of the cirrhotic cardiomyopathy syndrome has gained the dignity of a new clinical entity. Facing the availability of therapeutic interventions (paracentesis, transjugular intrahepatic portosystemic shunt, peritoneovenous shunt, orthotopic liver transplantation) currently employed to manage the life-threatening complications of the most advanced phases of cirrhotic disease, the knowledge of their impact on cardiovascular function is of paramount relevance.

INTRODUCTION

The syndrome of cirrhotic cardiomyopathy, first recognized in 1969 but mistakenly presumed to reflect latent alcoholic cardiomyopathy in patients with alcoholic cirrhosis, is now recognized to occur in all forms of cirrhosis, alcoholic and non-alcoholic, and thus is associated with cirrhosis *per se*. The hallmark of the syndrome is normal or increased ventricular contractility at rest, but depressed responsiveness to stimuli. In the past decade, many studies have demonstrated the clinical significance of this syndrome, from cardiac decompensation after surgery, cardiovascular procedures, therapeutic interventions targeted to manage the decompensated phase of cirrhosis and liver transplantation. Recent studies indicate that cirrhotic cardiomyopathy plays a key pathogenic role in hepatorenal syndrome. Indeed the past decade has seen an explosion of interest and awareness of this syndrome[1].

HEPATORENAL SYNDROME: CIRCULATORY CHANGES

Hepatorenal syndrome is one of the major complications of cirrhosis. As reported by Ginès et al[2], its annual incidence in patients with ascites is approximately 8%. The development of the hepatorenal syndrome entails a poor prognosis despite the progress in the therapeutic approaches elicited by the better knowledge of pathogenesis. As evidenced by Llach et al[3], parameters of renal function along with those related to cardiovascular derangement and activation of neurohumoral systems in decompensated cirrhosis are of paramount prognostic relevance. Since the beginning of the 1990's many studies have shown the major role of nitric oxide in the pathogenesis of circulatory dysfunction in cirrhosis[4]. It has been shown that arterial vasodilation involves mainly the splanchnic circulation with vasoconstriction being mainly expressed at the level of the muscles, the brain and the kidneys. Since vasodilation of the splanchnic arterial bed is linked to portal hypertension and nitric oxide is overexpressed in this vascular district, a interdependence between hepatorenal syndrome, circulatory derangement and liver cirrhosis has been clearly established[5]. Renal dysfunction in cirrhotic patients follows a progressive course: it starts with abnormalities in renal sodium handling initially unrelated with overactivity of the renin-angiotensin-aldosterone and the

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Recibido el 5-4-2005; aceptado para su publicación el 5-4-2005.

sympathetic nervous systems. With the progression of liver disease, however, the degree of sodium retention increases and overactivity of the neurohumoral systems becomes evident, targeted to maintain circulatory homeostasis, and mainly arterial blood pressure within the normal range. At this stage renal perfusion is protected by increased local production of vasodilatory prostaglandins, and possibly nitric oxide, counteracting the systemic and renal effects of endogenous vasoconstrictors. Increasing plasma levels of these neurohormones with progression of disease, usually in the ascitic stage, lead to reduction of glomerular filtration rate because of a fall in renal perfusion due to renal vasoconstriction. A marked increase in the plasma concentration of endothelins has been observed, but the pathogenic role of these vasoconstrictors in the development of the hepatorenal syndrome has been questioned. Nevertheless, renal function impairment could be the consequence of an imbalance between the overactivity of the systemic vasoconstrictor systems and local renal production of vasodilators. The evidence produced by many studies of the Barcelona group and by Laffi et al[6] that blockade of renal vasodilating prostaglandins by administration of nonsteroidal anti-inflammatory drugs is followed by deterioration of renal function supports this hypothesis. Renal ability to excrete free water is also markedly reduced at this stage, and most patients present dilutional hyponatriemia, which is mainly determined by the non-osmotic release of antidiuretic hormone: this leads to a progressive further expansion of the total blood volume up to the full-blown expression of the hyperdynamic circulation. The marked increase in the activity of the renin-angiotensin-aldosterone and sympathetic nervous system further increase the dynamic component of intrahepatic resistance and thus portal pressure. It is well known by studies performed by Fernández-Seara et al[7] and Maroto et al[8] that patients with cirrhosis and ascites without hepatorenal syndrome show a typical circulatory pattern of increased total plasma volume, cardiac index and heart rate, along with reduced peripheral vascular resistance and arterial pressure. But in the latest stages of cirrhosis, when the hepatorenal syndrome develops, the mechanisms of further derangement of cardiovascular function become even more complex because a decreased cardiac function is involved too. Indeed, hemodynamic studies performed by Tristani and Cohn[9] and Lebrec[10] have shown that cardiac impairment, and in particular a reduction in cardiac output, plays a key role in further circulatory derangement characterising the hepatorenal syndrome. A significant number of patients with hepatorenal syndrome exhibit arterial hypotension, reduced cardiac output, low right atrial pressure and wedged pulmonary pressures with a tendency for peripheral vascular resistance to be slightly higher than in ascitic subjects without hepatorenal syndrome. The surprisingly relatively increased peripheral vascular resistance can be explained as a response to the extreme counteregulatory activation of the endogenous vasoconstrictors, in the absence of which a dramatic fall of peripheral resistance would be expected. It is thus likely that all the factors involved in the pathogenesis of cirrhotic cardiomyopathy merge dramatically at this latest stages of disease unmasking impaired heart contractility previously elicitable only after strain. Therefore, circumstances requiring further increase in cardiac work, such as bacterial infections, or any other precipitating conditions leading to hepatorenal syndrome, such as digestive hemorrage, unveil cirrhotic cardiomyopathy.

SPONTANEOUS BACTERIAL PERITONITIS: CIRCULATORY CHANGES

Spontaneous bacterial peritonitis is an infection of ascites that occurs in the absence of a contiguous source of infection (e. g., intestinal perforation, abscess). In initial series published in the 1970's, when this clinical condition was first described, the mortality associated with an episode of spontaneous bacterial peritonitis exceeded 80%. Improved knowledge of pathophysiology and accordingly amelioration of therapeutic approach in the last years have reduced the mortality rate to 20-30%, as reported in recent prospective studies with well defined diagnostic criteria (Rimola et al[11], Navasa et al[12] and Llovet et al[13]). Still, mortality after a single episode of spontaneous bacterial peritonitis remains significant. Bacterial translocation, the phenomenon by which viable microorganisms from the gut lumen migrate to mesenteric lymphnodes and other extraintestinal sites, has been postulated as one of the main mechanism involved in the pathogenesis of spontaneous bacterial peritonitis.

Hemodynamic instability, progressive renal and hepatic failure, and hepatic encephalopathy are the clinical hallmarks of most patients dying from spontaneous bacterial peritonitis. Navasa et al[12] suggested that impaired renal function evolving in either type 1 or type 2 hepatorenal syndrome in spontaneous bacterial peritonitis is favored by a further deterioration of the background hyperdynamic circulation of cirrhosis promoted by cytokines. It has been proposed that this hampered circulatory dysfunction might be the consequence of an accentuation of arterial vasodilation: nevertheless, an impairment of cardiac function could arise via reduced ventricular contractility by a cytokine-mediated septic cardiomyopathy.

A recent study by Ruiz del Árbol et al[14] investigated the changes in systemic, renal and hepatic hemodynamics in cirrhotic patients with spontaneous bacterial peritonitis providing evidences that the cardiac dysfunction observed in this condition is a manifestation of cirrhotic cardiomyopathy. They studied 23 patients with spontaneous bacterial peritonitis by means of assessment of neurohumoral variables, plasma and ascitic fluid concentration of tumor necrosis factor-alfa (TNF-α), invasive hemodynamics (which included measurement of cardiopulmonary pressures, cardiac output and portal pressure gradient), systemic inflammatory response before and after cefotaxime administration. Eight patients developed renal failure, whereas the remaining did not. In the renal failure group cardiac output was lower, whereas peripheral vascular resistances, portal pressure gradient and degree of neurohumoral overactivity significantly higher. Mean ar-

terial pressure, heart rate and cardiopulmonary pressures did not differ within groups. In the whole series there was a significant inverse correlation between plasma and ascites concentration of TNF-α and the baseline values of cardiac output. Plasma and ascites TNF-α levels were significantly higher in patients with renal failure. During treatment cardiac output significantly decreased and portal pressure gradient increased in the renal failure group, with no changes in systemic vascular resistance, heart rate and cardiopulmonary pressures as compared to baseline values in either group. Six out of 8 patients who developed renal failure died.

This study underscores the complex nature of the circulatory dysfunction associated with renal failure in spontaneous bacterial peritonitis. In particular at the end of treatment, cardiac output was 32% lower and systemic vascular resistance 31% higher in the renal failure group, as compared to the group without renal failure, suggesting that circulatory dysfunction and renal failure in spontaneous bacterial peritonitis is related to a decrease in cardiac output. Systemic vascular resistance is also a major factor: the slightly increased values observed as compared with subjects without renal failure should be expected to be even greater due to the extreme activation of the counterregulatory neurohumoral systems, suggesting impaired pressor response. The reduced cardiac output seems to be in line with the evidences of impaired cardiac reserve in patients with cirrhosis and hyperdynamic circulation. A reduction in cardiac output, in the absence of a significant increase in cardiopulmonary pressures, is consistent with a decreased venous return to the heart. The unchanged heart rate, facing the differences in mean arterial pressure and sympathetic nervous activity along with unchanged right atrial and pulmonary wedged pressures between patients with and without renal failure, suggests a reduced stroke volume and impairment of cardiovascular reflexes.

However, common features are observed in sepsis, in which TNF-α notably plays a major role. As in septic cardiomyopathy, emerging evidence suggests that this and other cytokines, as interleukin 1β, depress myocardial contractility in cirrhosis via nitric oxide-dependent and independent pathways. It is thus conceivable that the observed contractile impairment in spontaneous bacterial peritonitis is a combination of septic and cirrhotic cardiomyopathy. Indeed, cardiac dysfunction in sepsis and cirrhosis bears remarkable similarities. Both conditions share hyperdynamic circulation and ventricular hyporesponsiveness. Unfortunately this study did not include an evaluation of diastolic function and thus a definite conclusion, but only a strong suspect on the contribution of impaired relaxation of the left ventricle and thus of diastolic dysfunction to the complex cardiovascular disturbance in this subset of patients, cannot be drawn.

A recently published study performed by Fernández et al[15] assessed systemic and hepatic hemodynamics in a consecutive series of cirrhotic patients with spontaneous bacterial peritonitis, in whom ceftriaxone administration was coupled with albumin infusion. The authors found that treatment with third generation cephalosporins and albumin prevents circulatory and renal dysfunction in these patients. They also observed an increase in right atrial pressure, pulmonary arterial pressure and capillary pulmonary pressure, and a marked deactivation of the renin-angiotensin system. These data are consistent with a sustained expansion of the central blood volume. In this study these findings were associated with an improvement in cardiac function, as manifested by an increase in left ventricle systolic volume and stroke work index, which explains why the cardiac index was maintained despite a significant decrease in heart rate. However, this does not explain the significant increase in mean arterial pressure observed in the study which was mainly related to an increase in systemic vascular resistance. The improvement in the peripheral circulation observed in these patients was remarkable considering that the significant increase in systemic vascular resistance occurred in the setting of an intensive deactivation of the renin-angiotensin system. At variance with the observations of Ruiz-del Árbol el al[14], therapeutic plasma expansion with albumin, as proposed by Fernández et al[15], protects from hypovolemia. Differences in hemodynamic changes between the 2 studies could not be attributed to differences in infection resolution, but rather to the administration of albumin. In the study by Fernández et al[15], the authors did not observe significant changes in portal pressure and hepatic blood flow.

LIVER TRANSPLANTATION AND CARDIAC DYSFUNCTION

Liver transplantation can be considered as the ultimate therapeutic option for cirrhotic patients with complications of disease not otherwise amenable. However, transplant constitutes a major physical stress for the cardiovascular system during both the trans-operative and the post-operative period. Myers and Lee[16] have recently reviewed this topic, underlying the relevance of preoperative assessment of cardiovascular function in cirrhotic transplant candidates: indeed, overt left ventricular failure has emerged as a significant cause of peri-operative morbidity and mortality in the liver transplant recipient. Donovan et al[17] have preoperatively investigated by 2-dimensional and dobutamine stress echocardiography cirrhotic patients with end-stage disease before liver transplantation. They reported a 56% incidence of acute pulmonary edema during the early post-operative period. Intra-operatively cardiac output may either decrease because of reduced preload (third-space losses, acute anemia leading to hypovolemia, clamping devices on major veins reducing venous return) or impaired myocardial contractility (volume overload after aggressive fluid replacement strategy).

7-21% of postoperative deaths after liver transplantation are linked to heart failure. Nasraway et al[18] reported evidence for early post-operative myocardial depression and Spanier et al[19] identified heart failure as an independent predictor of mortality after liver transplantation. Beyond

the trans-operative stress, cardiac performance may be hampered post-operatively as a consequence of changes in the cardiovascular system. The progressive normalization of the hyperdynamic circulatory state after the removal of the cirrhotic liver and secondary to the increase in peripheral vascular resistance and normalization of mean arterial pressure may contribute to the occurrence of heart failure because of sudden increase in afterload. Sampathkumar et al[20], in a retrospective analysis of over 700 cirrhotic patients undergoing liver transplantation at the Mayo Clinic, have described myocardial dysfunction after liver transplantation: they have observed a reversible form of dilated cardiomyopathy during the early post-transplant phase, with clinical manifestation of acute pulmonary edema and respiratory failure. Echocardiography revealed dilatation of all cardiac chambers and marked reduction of the ejection fraction. All patients subsequently showed resolution of their cardiac dysfunction with ejection fraction gradually increasing to a median of 50%, without recurrent heart failure within the following follow up period of 15 months after transplantation.

Cardiovascular system alterations during the post-transplant period remains a controversial issue. Navasa et al[21] support the contention that most of the neurohumoral and hemodynamic changes characterizing advanced liver disease are rapidly abolished after the transplant. However, Henderson[22] suggested a residual hyperdynamic circulatory pattern in transplanted patients. Acosta et al[23], on the contrary, claimed that cirrhotic patients presented normal cardiac performance during either the pre- and post-transplant period, casting doubts on the existence of cirrhotic cardiomyopathy. Nevertheless, in a following study by the same group[24] they described after liver transplantation an increase in percentage of patients with abnormal ejection fraction. They postulated a role for increased afterload on one side, due to the reversion of the hemodynamic alterations characteristic of cirrhosis, and for the effects of immunosuppression with cyclosporine. The most relevant finding of their study was a decreased diastolic function after liver transplantation possibly linked to immunosuppressive therapy and/or high dose steroids that could induce an increase in cardiac wall thickening and abnormal left ventricular filling in the heart of organ recipient. After transplant González et al[25] have shown the reversibility of QT prolongation, one of the electrophysiological abnormalities in the scenario of the cirrhotic cardiomyopathic disease.

It is thus clear that there is need for thorough investigations to assess the effects of liver transplantation on the cardiovascular status in cirrhotic patients, even if some studies have evidenced the unpredictable, albeit often reversible, nature of this disorder. Meanwhile, accurate assessment of cardiovascular function before liver transplantation is deemed to be necessary. Recent reports indicated the role of dobutamine stress echocardiography[26,27] or myocardial perfusion scintigraphy[28] before transplant, but further and more conclusive studies are obviously awaited. This because dobutamine stress echocardiography might be a rather insensitive test: actually this drug increases myocardial oxygen consumption mainly by increasing myocardial contractility without relevant increases in afterload; that is the major challenge faced by the heart in the post-transplantation setting.

No specific therapy can be advocated for this condition, and thus management is largely empirical, mostly based on the current management of non-cirrhotic causes of cardiomyopathy. The use of dobutamine is unlikely to be effective due to the specific inotropic effect of this drug targeted on β-receptors, which are notably desensitized in cirrhotic cardiomyopathy.

THE IMPACT OF TREATMENT OF ASCITES ON CARDIOVASCULAR FUNCTION. PARACENTESIS, TRANSJUGULAR INTRAHEPATIC PORTOSYSTEMIC SHUNT (TIPS), LE VEEN SHUNT

Brief summary on management of ascites

A «stepped-care» algorithm in the management of ascites in cirrhosis consists of the progressive implementation of the therapeutic measures currently available, including bed rest and low-sodium diet along with increasing doses of aldosterone antagonists (up to a maximum dose of 400 mg of spironolactone) and then of loop diuretics (up to 160 mg of furosemide). A second approach can be termed «combination treatment», with simultaneous administration of both drugs with progressive stepwise (4 days) increases up to the same top-level schedule. It has been estimated that true refractory ascites, requiring alternative therapeutic approaches, is a relatively infrequent condition, as it occurs in less than 10% of patients admitted to hospital for the treatment of an episode of ascites[2].

However, even well conducted therapeutic schedules with these 2 drugs are not free from adverse effects which may require dose adjustments or even withdrawal. The evidence of side-effects of diuretics prompted the studies that led to the resurrection of paracentesis as an alternative approach for the treatment of diuretic-resistant (ascites not responding to maximum allowed doses of diuretics) and diuretic intractable (ascites that cannot be treated with the expected doses of diuretics due to development of side-effects) ascites as indicated by the International Ascites Club recommendations included in the special article «Definition and diagnostic criteria of refractory ascites and hepatorenal syndrome in cirrhosis»[29]. In this subset of patients, as well as in those presenting tense ascites, paracentesis and other procedures should be considered.

However, cardiac alterations are more frequently encountered in cirrhotic patients with ascites: moreover, a mechanical hindrance can further impair heart function when tense ascites develops. The main reasons are that: *a)* these patients experience more advanced hemodynamic and neurohumoral alterations than pre-ascitic cirrhotics, and *b)* the presence of ascites *per se* may cause increased intrathoracic pressure and bulging of the diaphragm, which could mechanically interfere with the physiologic cardiac movements during contraction and relaxation. Patients

with cirrhosis and ascites may need large volume or total paracentesis or may become candidates for TIPS or peritoneovenous shunting (Le Veen shunt, Denver shunt) if ascites becomes «refractory». All these procedures may require further cardiac and haemodynamic adaptation. An increasing number of investigations in the last few years have focused their attention on the development of cardiac abnormalities in these patients, and the term «cirrhotic cardiomyopathy» has been proposed to include the different structural and functional alterations observed. Symptoms of cardiac impairment at rest may not be apparent even in these patients with far advanced liver failure; however, under physiological, pharmacological or «procedural» stress, the ventricular systolic function may give inadequate response. Therefore it has been suggested that special caution should be used when procedures that may cause acute changes in systemic hemodynamic are applied in these patients.

Paracentesis

A great deal of information has been obtained in the last years indicating that therapeutic paracentesis is a safe, rapid and effective therapy for ascites in cirrhosis, and it is currently considered the treatment of choice for tense or grade 3 ascites, provided plasma expansion is warranted to prevent the systemic circulatory disturbance that may follow if this measure is not applied.

Despite no differences in long term mortality between cirrhotic patients with huge ascites treated with high dose diuretics and large-volume or total paracentesis, many studies have clearly indicated that paracentesis, followed by diuretics as maintenance therapy, can be considered the treatment of choice. This is based on the evidence that: *a)* the incidence of renal functional impairment and hepatic encephalopathy is significantly greater in diuretic-treated patients; *b)* ascites resolution, and accordingly relief of symptoms, is faster in paracentesis-treated subjects, and *c)* hospital stay is shorter after paracentesis with a better cost-effectiveness profile, despite the relatively high cost of albumin.

Indeed, after the first classic studies performed by Quintero et al[30], Ginès et al[31] and Tito et al[32] of the Barcelona group examining the effects of either large-volume or single total paracentesis as compared to diuretics in the clinical management of tense-refractory ascites, it became clear that therapeutic plasma expansion with albumin after paracentesis prevents the hemodynamic derangement that may ensue after the unequivocal early beneficial circulatory effects. Several hemodynamic investigations have carefully examined the circulatory and neurohumoral effects of either large volume or total paracentesis and allowed to identify 2 distinct phases: the first, or early phase (during and within the first 12 h after the drainage of ascitic fluid), is characterized by an overall circulatory improvement, whereas the second, or late phase, can be characterized by a deterioration of circulatory and neurohumoral parameters that may become particularly critical in absence of therapeutic plasma expansion when the volume of ascites drained is more than 5 l. Guazzi et al[33], Simon et al[34], Panos et al[35] and Pozzi et al[36] examined the hemodynamic adaptative changes to ascites removal by paracentesis (approximately 10 l) in cirrhotic patients with either tense or refractory ascites. In particular, the studies performed by the last 2 authors provided detailed information also on the time-course of the changes of the hemodynamic and neurohumoral variables already during the procedure. Briefly, the main circulatory and neurohumoral effects of large volume or total paracentesis can be summarized as follows. The early effects consist of a reduction of right atrial pressure, pulmonary capillary wedge pressure, mean arterial pressure, systemic vascular resistance, plasma renin, aldosterone, norepinephrine, intraabdominal pressure, intrathoracic pressure, and an increase in stroke index, left ventricular diastolic and systolic volumes, cardiac index and atrial natriuretic peptide concentration. All these changes denote improved cardiac performances and possibly increased venous return due to the fall in intraabdominal and intrathoracic pressures, ultimately translating in increased cardiac transmural pressures. The late effects are characterized by a reduction of cardiac output to baseline values, a further decrease of systemic vascular resistance and a marked activation of the renin-angiotensin-aldosterone system and sympathetic nervous system, which can reach values higher than pre-paracentesis levels. Thus the first phase is characterized by an expansion of the intravascular volume and the second by a progressive reduction of the effective intravascular volume. Many studies have provided evidence that the expansion of the intravascular volume by means of albumin administration at a dose of 6-8 g/l of ascites drained (and to a lesser extent by synthetic plasma expanders) prevents the occurrence of impairment in intravascular volume following ascites drainage by paracentesis. A later study by Pozzi et al[37] corroborated the notion of the protective role of therapeutic plasma expansion after paracentesis on hemodynamic stability by demonstrating the sympathoinhibitory effects of paracentesis followed by albumin administration, at least in the short term, as evidenced by the reduction of the sympathetic nerve traffic at the muscle district by means of intraneural recordings along with the other neurohumoral variables. Luca et al[38] further confirmed the beneficial effects of intravenous albumin infusion on the hemodynamic and humoral changes after total paracentesis. A group of cirrhotic patients with tense ascites was randomized to receive albumin infusion or not at the end of the procedure. In untreated patients cardiac index, femoral blood flow and pulmonary capillary pressure reduced, along with a significant increase in neurohumoral variables and reduction of atrial natriuretic peptide. Portal pressure gradient and portocollateral flow reduced in both groups returning to baseline thereafter.

Other numerous studies[39-43] have extensively evaluated the protective role on intravascular volume changes induced by paracentesis followed by infusion of synthetic plasma expanders, notably less expensive than human al-

bumin. These studies concluded that an impairment of circulatory parameters can occur in 60-70% of patients submitted to paracentesis without any therapeutic plasma expansion, in 30-40% of patients treated by paracentesis followed by infusion of synthetic plasma volume expanders (like dextrans or polygeline), and in 18% of subjects treated with albumin infusion (8 g/l of ascites drained). Thus an inverse relationship between the incidence of hemodynamic derangement after paracentesis and the half-life of the plasma expander employed seems to exist. Ruiz del Árbol[44] characterized the circulatory impairment that follows total paracentesis followed by synthetic plasma expander administration (dextran 70 infusion). Nearly 30% of patients developed «post-paracentesis circulatory dysfunction», which is mainly caused by an accentuation of the arteriolar vasodilation already present in untreated cirrhotic patients with ascites. This is followed by a further increase in the homeostatic activation of the neurohumoral systems, which in turn brings about a further increase in intrahepatic vascular resistance. Ginès et al[45] reported that the development of this syndrome is associated by a shorter probability of survival. Actually, no one study has addressed the issue of whether post-paracentesis circulatory dysfunction can be considered as a condition favored by pre-existing cirrhotic cardiomyopathy so far.

A recently published study by Vila et al[46] compared the hemodynamic changes after paracentesis in patients who did or did not develop post-paracentesis circulatory dysfunction. Patients with post-paracentesis circulatory dysfunction are those who show the greater reduction in mean arterial pressure and systemic vascular resistance after paracentesis. The cause of the reduced systemic vascular resistance appears an enhanced arteriolar vasodilatation. Post-paracentesis hypovolemia stimulates the renin-aldosterone and sympathetic nervous system as a compensatory mechanism in order to maintain circulatory homeostasis. Plasma renin activity, aldosterone and norepinephrine are significantly increased in these patients after paracentesism and plasma renin activity increase closely correlates with the decrease of systemic vascular resistance. Again, one could speculate if cardiac dysfunction could be somehow involved in the pathogenesis of post-paracentesis hypovolemia; however, parameters of systolic function were not different in patients who did or did not develop this syndrome. No data are at present available on possible differences regarding left ventricle diastolic function impairment.

In conclusion, the large body of evidence indicates that overall favorable circulatory effects follow paracentesis when therapeutic plasma expansion with albumin is warranted. If less than 5 l are drained, synthetic plasma expanders may be equally effective. Human albumin is necessary when larger volumes of ascites are drained.

In the setting of truly refractory ascites of cirrhosis 4 potential therapeutic options are currently available. Repeated large volume paracentesis plus albumin infusion is the most widely employed therapeutic approach because of relatively low rate of complications and practical readiness as outpatient. Liver transplantation is the best option, when feasible, due to the low survival expectancy of patients with this condition. Peritoneous shunting is accompanied by high rate of complications and is becoming less frequently employed in many centers. TIPS, a non surgical method of portal decompression functioning as a surgical side-to-side portacaval shunt, has gained widespread popularity that led to head to head comparisons with paracentesis.

Transjugular intrahepatic portosystemic shunt (TIPS)

Ascites develops as a direct consequence of portal hypertension. Sinusoidal and post-sinusoidal portal hypertension are mainly associated with the development of ascites. In such cases, the development of portal hypertension is associated with changes in systemic hemodynamics and renal sodium and water retention with accumulation of fluid in the peritoneal cavity. TIPS involves the creation of a low-resistance channel between the portal and hepatic veins which decompresses the portal vein ultimately reducing portal pressure. Thus, by this reduction, TIPS ameliorates a fundamental pathophysiologic abnormality in patients with refractory ascites. TIPS is the more recent treatment introduced for the management of portal hypertension and from a theoretical point of view it should correct the 2 main factors involved in ascites development: *a)* by reducing portal pressure it should decrease the degree of splanchnic arterial vasodilation as well as ameliorate the arterial vascular underfilling, accordingly suppressing the endogenous vasoconstrictor systems, improving renal perfusion and thus restoring response to diuretics, and *b)* by decompressing the splanchnic and hepatic microcirculation, it should decrease the production of lymph, both in the liver and splanchnic organs, thus avoiding saturation of the capacity of this drainage system capable of a daily removal of up to 1 l of fluids. Actually the more frequent indications for TIPS are bleeding esophageal varices not responding to endoscopic therapy and refractory ascites.

Studies dealing with hemodynamic and cardiac changes after TIPS procedure mainly included patients selected as being in stable hemodynamic conditions and presumably without overt cardiovascular pathologies.

Short-term hemodynamic changes after TIPS

When a shunt is created between the hepatic and the portal vein (a kind of portacaval fistula), the high splanchnic blood flow is delivered to the systemic circulation. Thus, within minutes of TIPS placement, the cardiac output rises and the systemic vascular resistance decreases. This is followed by both an increase in left-sided filling pressures (pulmonary capillary wedge pressure) as well as right atrial pressure. The decrease in systemic vascular resistance is a physiological response to accommodate the increase in cardiac output and should not be looked at as an impairment in systemic hemodynamics. The mean pul-

monary arterial pressure generally rises due to both increased pulmonary vascular resistance and pulmonary blood flow. The latter is directly due to increased return of blood flow from the portal bed to the systemic circulation due to TIPS itself, while the former is possibly related to both increased pulmonary venous hypertension and neurohumoral factors. In some cases frank heart failure with development of pulmonary edema has been noted. Those with pre-existing pulmonary hypertension are particularly prone to develop right-sided volume overload with increased ventricular end-diastolic volumes. Indeed, several studies performed by various authors (Azoulay et al[47], Stanley et al[48], Huonker et al[49]) have reported an aggravation of the hyperdynamic circulation. This observation has initially raised some doubts on the beneficial effects of this procedure in cirrhotic patients.

The increase in cardiac output after TIPS is mainly due to the increased cardiac refilling secondary to shunt opening. Merli et al[50] measured the intrathoracic blood volume immediately after TIPS and an increase of this compartment was clearly evidenced. Moreover, the percent increase of intrathoracic volume directly correlated with the percent increase of cardiac output.

Two mechanisms have been invoked to explain the decreased systemic vascular resistance induced by TIPS: *a)* a decrease in the vasopressor system (catecholamines and renin-angiotensin-aldosterone) due to better cardiac filling, and *b)* an increased availability of vasodilator substances in the systemic circulation due to opening of the shunt. Studies on changes of vasodilator substances after TIPS have shown conflicting results (Merli et al[50], Martinet et al[51]), while many studies reported a decrease in plasma concentration of endogenous vasoconstrictors after TIPS (Jalan et al[52], Salerno et al[53]). These early hemodynamic modifications induced by TIPS (right atrial pressure, pulmonary arterial pressure and pulmonary capillary wedged pressure increase) have been interpreted as a consequence of an initial inability of the filling capacity of the right ventricle to cope with the shunted blood volume. However, this phenomenon is rather transient, indicating that the heart is able to increase its work so as to cope to this stressful condition. In agreement with the above considerations, changes in echocardiographic parameters documenting cardiac modifications have been reported one month after TIPS. These include increased left ventricular diastolic diameter, left ventricular systolic diameter and estimated pulmonary arterial pressure and reduced pre-ejection period and isovolumic relaxation time. All authors claim that a sufficient cardiac reserve is necessary to meet the demands of the post TIPS short-term modifications.

Medium and long-term haemodynamic changes after TIPS

Some studies reported data about the modifications of haemodynamic status and cardiac function in cirrhotic patients 2 to 12 months after TIPS. Jalan et al[54] showed that the cardiac index after TIPS returned to normal values after 2 months, suggesting an adaptation of the heart to handle the increased preload, despite persistently low peripheral vascular resistance. Merli et al[50] observed that echocardiographic changes suggesting modifications in cardiac function were completely reversed in 11 patients with non alcoholic cirrhosis after 6-9 months, also suggesting a good adaptation of cardiac function to increased pre-load. In another series of 21 patients treated with TIPS, at 3 months, Lotterer et al[55] showed that all cardiovascular and humoral parameters had returned to baseline levels, except a slight persistent increase of carbon monoxide, which completely normalized when patients were re-evaluated one year later after TIPS placement.

A recent study by Salerno et al[56] compared the effects of TIPS in 2 groups of patients: those with high plasma renin activity resting levels (> 4 ng/ml/h), identified as those with effective hypovolemia before TIPS, and those without hypovolemia (plasma renin activity < 4 ng/ml/h). A large majority of the «hypovolemic» patients had a more severe degree of liver dysfunction and TIPS performed for refractory ascites; all but one patients in the other group received TIPS for bleeding esophageal varices. Although patients with known cardiovascular disease were excluded from the study, echocardiographic parameters assessed before TIPS were more frequently altered in the «hypovolemic» patients (lower stroke volume and left ventricular volumes, reduced E/A ratio, suggesting the presence of diastolic dysfunction). The TIPS procedure induced exacerbation of the hyperkinetic circulation in both groups, as previously reported. In the «hypovolemic» patients, plasma renin activity decreased and atrial natriuretic factor increased, indicating redistribution of liquid compartments and improved filling of the central part of circulation. Moreover, in these patients, TIPS procedure improved cardiac performance as shown by an increased left ventricle end-diastolic volume and stroke volume, and a tendency of the E/A ratio to normalize. The ability to transiently increase the cardiac hemodynamic work (cardiac output and stroke volume) may represent a good prognostic index for «hypovolemic» patients treated with TIPS.

In conclusion, the role of TIPS in the management of refractory ascites is evolving. Refractory ascites can be mobilized in up to 90% of patients. However, the choice of the patients to be submitted seems to be a relevant issue because in those subjects with moderate liver dysfunction TIPS can frequently mobilize ascites and convert diuretic-resistant ascites to diuretic-sensitive, ameliorate liver function, nutritional status and probably quality of life. The same does not seem to be the case in subjects with more relevant liver dysfunction (Child C), who are notably more prone to develop hepatic encephalopathy and further deterioration of liver function after TIPS placement. Indeed hepatic encephalopathy is the most common complication of TIPS. More than 40% of patients develop post-TIPS hepatic encephalopathy. Although hepatic encephalopathy prior to TIPS is a predictor of post-TIPS encephalopathy, new onset or worsening of hepatic encephalopathy develops in approximately 30% of cases, most

of which responding to common treatment. Shunt dysfunction is another problem. It occurs in 40% of patients treated without the so-called covered stents (those preventing intimal proliferation that leads to shunt obstruction) that since their recent introduction have actually reduced the occurrence of this problem.

The relevant issue of pre-TIPS assessment of cardiac function and cardiac reserve must be underscored in order to prevent, facing the evidences previously mentioned, cardiac malfunction after the procedure. Finally, the effects of TIPS on survival, even in those patients with only mild-to-moderate liver failure, remains to be clarified. At present 4 large-scale randomised controlled trials of TIPS versus serial large volume paracentesis have been published. Three of these report better ascites control in the TIPS group, with higher incidence of hepatic encephalopathy, higher cost and no clear evidences on overall survival. The recently published trial by Salerno et al[53] reports a survival advantage for TIPS-treated patients. However, only one of these studies (Sanyal et al[57]) provided a specific cut-off of cardiac ejection fraction (> 50%) for eligibility to enrolment. However, the ejection fraction of patients with cirrhosis is usually greater than 60%. Azoulay et al[47] have recently suggested that an ejection fraction of greater than 60% may be more appropriate as an inclusion criterion for entry in a TIPS study, since patients with an ejection fraction between 50% and 60% may have a higher risk of post-TIPS heart failure secondary to failure in handling the blood volume returned from the splanchnic circulation immediately after TIPS insertion. As the experience with TIPS continues, and the level of sophistication of patient screening improves (e. g., with the routine assessment of the ejection fraction at enrolment) along with improvement of the technology of the stent itself (polytetrafluoroethylene-covered stents), the results of future trials may be better than those of past trials.

Peritoneovenous shunt

In the early seventies Le Veen[58] first devised and introduced the peritoneovenous shunt as a prosthetic system specifically designed to treat patients with refractory ascites. It consists of a multiperforated plastic tube that connects the intraabdominal cavity with the jugular vein (by subcutaneous positioning under local anesthesia) via a unidirectional pressure-sensitive valve. The intravenous portion of the tube is positioned up to the superior vena cava, close to the right atrium. It is advisable to remove by paracentesis most of the ascitic fluid from the peritoneal cavity in order to avoid immediate passage of massive quantity of ascitic fluid in the systemic circulation with risk of acute cardiac overload.

After positioning, the shunt produces a sustained expansion of the circulating blood volume by the intermittent passage of ascitic fluid, through the pressure-sensitive valve, into the systemic circulation. Most studies published by the Toronto group showed that the shunt produces an almost immediate rise in mean right atrial pressure and increase in cardiac output, a decrease in peripheral vascular resistance, a marked but slow suppression of the plasma levels of renin, catecholamines and antidiuretic hormone, a sustained and very rapid increase in atrial natriuretic peptide, urinary volume and sodium excretion, ultimately improving the response to diuretics at smaller dose as compared to that required pre-shunt and amelioration of the nutritional status in the long term.

All these findings are consistent with the combined effects of increased right atrial pressure induced by volume expansion leading to stimulation of atrial natriuretic peptide secretion via atrial stretching. Therefore, it appeared as a very rational therapeutic approach to refractory ascites. However, in the long term the patients tend to remain hypotensive with decreased peripheral vascular resistance in presence of relative suppression of systemic and renal sympathetic nervous system overactivity (reduced renal norepinephrine production) and evidence of a still impaired renal sodium handling: this implies that factors other than the renin-aldosterone system and the sympathetic nervous system are involved in the control of sodium excretion in cirrhotic patients with refractory ascites treated with the Le Veen shunt.

The peritoneovenous Le Veen shunt caused initial enthusiasm and was initially advocated as the treatment of choice for severe ascites and even hepatorenal syndrome. However recent studies demonstrated a hospital mortality of up to 30% and a one-year survival no better than 30%. Moreover, up to 70% of the shunts are occluded within the first post-operative year: this occurs as a consequence of deposition of fibrin within the valve or around the venous portion of the catheter or even thrombosis of the superior vena cava and infection of the shunt. It has been proposed that other peritoneovenous prosthesis (Denver shunt) or the insertion of a titanium tip at the venous extremity of the Le Veen shunt could reduce the incidence of shunt occlusion, but these contentions have not been corroborated by the results of randomised controlled trials (Ginès et al[59] and Henriksen et al[60]). Moreover, peritoneal fibrosis or even intestinal obstruction observed after shunt positioning may hamper liver transplantation. Thus, poor long-term patency, excessive rate of complications requiring frequent hospitalisations and no survival advantage compared to medical therapy in controlled trials have led to virtual abandonment of this procedure in most hepatology centres worldwide (Suzuki and Stanley[61], and Ginès et al[2]).

In conclusion, it is well known that hemodynamic and cardiac alterations are more frequent and relevant in ascitic cirrhotic patients. These patients are treated with large volume paracentesis followed by the infusion of plasma volume expanders and may become candidates for TIPS or to liver transplantation. All these procedures may induce haemodynamic modifications and require cardiac adaptation.

Paracentesis decreases the intrathoracic pressure, improves venous return to the heart and therefore facilitates cardiac function. Right atrial pressure and systemic pul-

monary resistance decrease and cardiac index improve after this procedure. Systemic vascular resistance after paracentesis decreases. However, this physiological hemodynamic adaptative change to cope increased cardiac output may become dramatically pronounced in those patients developing post-paracentesis circulatory dysfunction. At present there are not sufficient information as to whether cardiac function is directly involved in the development of postparacentesis circulatory dysfunction.

After TIPS opening, a large amount of the splanchnic blood flow is delivered to the heart inducing an increase in ventricular preload. In the short term, TIPS induces an increased right atrial and pulmonary resistance, which may suggest an initial inability of the right ventricle to cope with the shunted blood volume. Echocardiographic changes however demonstrate a rapid cardiac adaptation to increased pre-load resulting in increased cardiac output and stroke volume even in those patients who were «hypovolemic» and showed initial signs of diastolic dysfunction before TIPS.

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