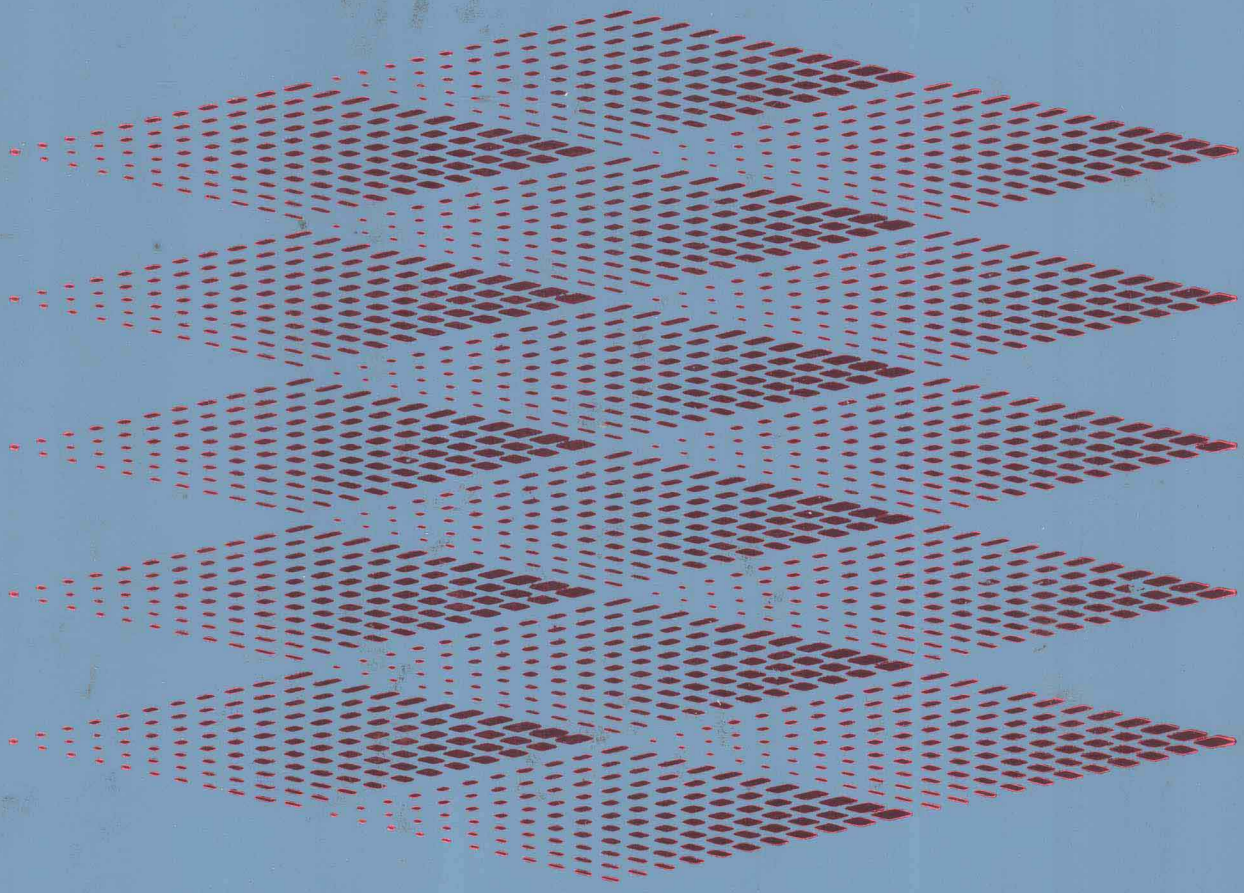
Radiology of Organ Transplantation



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FOREWORD

The field of organ transplantation has grown remarkably in the past 36 years since the first successful kidney transplant between identical twins. Livers, pancreases, hearts, heart-lungs, and single and double lungs have been added to the array of organs used for clinical transplantation. These remarkable accomplishments have resulted in the development of multiorgan transplant units, which owe their success primarily to teamwork between nurses, transplant coordinators, sociologists, and many other health professionals.

Internists in nephrology, hepatology, diabetology, cardiology, and pulmonology have played an integral part in treating patients with endstage disorders of these various solid organs. Also crucial has been the strong support from laboratory specialists such as virologists, bacteriologists, immunologists, geneticists, and pharmacologists. Better immunosuppressive drugs and sophisticated imaging techniques to evaluate organ function have proved equally important.

Thus, the time had definitely come for a text on the role of radiology in the field of solid organ transplantation. Dr. Janis Letourneau has edited this extremely valuable contribution to the literature. Part I looks at complications arising secondary to transplantation in general. Parts II through V describe the role of imaging techniques for renal, hepatic, pancreatic, and finally heart and heart-lung transplantation. The use of various imaging modalities is beautifully illustrated and thoroughly discussed. Following a clinical and surgical overview of each specific organ transplant, this remarkable compilation was achieved with the aid of internists, surgeons, radiologists, pathologists, pediatricians, cardiologists, pulmonologists, and diabetologists, all in a single institution. Focusing on the University of Minnesota, it presents a true, state-of-the-art snapshot of the radiologic aspects of multiorgan transplants today.

This invaluable guide will be an essential clinical resource for radiologists dealing with transplant patients. It will also be a necessity on the bookshelves of transplant surgeons and all physicians, and health care workers involved in this miraculous field of organ replacement.

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FOREWORD

Most people want to die suddenly. Oliver Wendell Holmes' "Wonderful One Hoss Shay" said it best: "All at once and nothing first, just as bubbles do when they burst." Most of us are not so lucky; we wear out piece by piece. It is the function of the now mature—but still evolving—field of organ transplantation to replace the organs as they deteriorate.

Most contributors to the current book, edited by Dr. Letourneau, are from the University of Minnesota, an institution in which I worked for nearly 20 years. Many of the images in this book are of patients who were treated during that time. The book is, in fact, an extraordinary compilation of our complications, and as such it will be of extraordinary value as an encyclopedia of transplantation complications. Some complications are not so frequent as before, but others—technical, infectious, and malignant—will be around until nonspecific immunosuppression is replaced by true immunologic tolerance.

Dr. Letourneau's editorial efforts have been well-rewarded. This is an extraordinary book, and I do mean extraordinary. We should be grateful to her for the splendid way in which she has accomplished her task, and for the many contributors who have participated with her in this project.

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PREFACE

This book is directed at radiologists, surgeons, and internists who care for transplant recipients, or who are interested in solid organ transplantation. Because transplantation is rapidly becoming relatively commonplace, experience with related imaging and radiologic intervention is developing in a parallel fashion. The purpose of this book is to integrate, organize, and present the existing data on imaging in relation to kidney, liver, pancreas, heart, heart-lung and lung transplantation in a readable and well referenced format. Ample illustrations supplement the chapter texts to facilitate the task of presenting this large amount of information. These chapters provide a basis of understanding of the pathophysiology of complications of solid organ transplantation, and the existing standards of imaging and radiologic intervention for these complications. This approach will, hopefully, provide a foundation for modifying the diagnostic and therapeutic approach to the transplant patient as our understanding of complications improves, and as imaging technology develops further.

We are very grateful to a number of people who helped initiate and complete this project, including Dr. William M. Thompson, who provided departmental resource support, and Drs. Wilfrido R. Castañeda-Zúñiga, John S. Najarian, and Richard L. Simmons, who encouraged us from the outset. Martin Finch, Director of Biomedical Graphics Communications at the University of Minnesota, coordinated the artwork and radiographic reproductions. James D. Ryan and Anne S. Patterson at Mosby–Year Book, Inc. facilitated the project. Finally, a project of this size cannot be completed without superb secretarial support; for the innumerable tasks fulfilled, we are grateful to Hiltje Loyd, Kris Schwaab, Carla Nelson, Judy Muermann, Helen Durgin, and Audrey Chan.

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PART ONE

General Radiologic Considerations of Solid Organ Transplantation

Chapter 1

Perspectives on the Radiology of Organ Transplantation

Janis Gissel Letourneau, M.D.

In many instances of end-stage organ failure, organ transplantation has moved beyond an experimental status, into the category of treatment of choice. This is true for end-stage renal disease in patients of most age groups and for many patients with hepatic and cardiac disease. Technical developments in these transplantation procedures will undoubtedly continue to occur, changing the indications for different types of transplantation procedures and, consequently, changing the indications and needs for different types of radiologic examinations and interventional procedures in the recipients.

Although a tremendous amount of animal investigation and laboratory work has been undertaken over the past 30 years, particularly involving immunologic and rejection phenomena, our understanding of the clinical complications that occur after solid organ transplantation is incomplete. Our knowledge of these complications has increased greatly in recent years and certainly is enhanced by the careful record keeping of the transplantation registries. Additionally, our understanding of these clinical complications has to a certain extent paralleled development of our understanding of their imaging characteristics.

The explosion of technological developments in both diagnostic and interventional radiology in recent years has changed the diagnostic approach to the evaluation of the transplant recipient. Nonetheless, the complexity of the clinical situations these patients present often renders a single diagnostic radiologic examination incomplete for diagnosis; consequently, radiologic tests are often complementary in resolving diagnostic issues.

The complexity of clinical problems in these patients coupled with the dramatic developments in imaging technology also seem to make the writing of a text such as this a rather hopeless endeavor. In fact, we delayed execution of this book by 18 months because of the rapidly expanding experience with the radiology of organ transplantation being reported in the literature. Our hope is that this text offers a foundation for planning, executing, and understanding the radiologic evaluation and treatment of transplant recipients now and in the future. Undoubtedly, as refinements in transplantation procedures occur and as experience with both noninvasive and invasive radiologic procedures grows, application of diagnostic and interventional radiologic procedures in organ recipients will change.

In the future we are likely to see some major changes in the use of particular types of organ transplantation. It is likely that we will see the increased use of partial hepatic transplants to serve either as the sole or auxiliary liver in patients with end-stage hepatic disease. The need for such procedures will be due in part to the limited supply of donor organs and in part to the small size of many pediatric candidates. Additionally, we might expect an increased performance of hepatic transplantation in the setting of malignancy, particularly in children with malignancy. It is likely that we will see more routine performance of pancreas transplantation as well, as our ability to monitor pancreatic function improves and the treatment or prevention of graft rejection evolves. We appear to be rapidly evolving to a preference of lung transplantation over combined heart-lung transplantation as some of the technical problems and hemodynamics of this procedure are better understood. The role of the radiologist, clearly, is to stay abreast of changes in philosophical and surgical approaches to solid organ transplantation; doing this will optimize the diagnostic and interventional radiologic management of these patients and their complications, acknowledging the vital role that the radiologist plays on the team of physicians caring for the transplant recipient.

Chapter 2

Radiographic Assessment of the Potential Recipient and Donor Before Solid Organ Transplantation

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The preoperative evaluation of a potential solid organ recipient is extensive and includes a large number of medical, radiologic, and psychological tests. Donor evaluation prior to solid organ transplantation is considerably more limited, particularly as it relates to radiographic studies, except for special circumstances of renal and heart or heart-lung transplantation.

The basic principle of potential recipient radiographic evaluation is to exclude the presence of focal or systemic infection and malignancy, as subsequent immunosuppressive therapy to maintain graft survival predisposes to rampant progression of infectious or malignant processes. Consequently, all potential recipients undergo chest radiography to exclude pulmonary infection or malignancy. If questionable or definitive abnormalities are present, chest computed tomography (CT) may be done. In older patients or in patients with abdominal symptoms, abdominal CT may also be done. Right upper quadrant sonography is performed to evaluate for cholelithiasis; cholecystectomy is done before transplantation in symptomatic patients and at transplantation in asymptomatic patients when gallstones are present.[1] Similarly, a conventional barium upper gastrointestinal series is recommended in potential organ recipients to exclude the presence of peptic ulcer disease.[1, 2] In the past, patients with peptic ulcer disease underwent pretransplant vagotomy and pyloroplasty to reduce the risk of significant posttransplantation upper gastrointestinal complications related to the stress of the operation and to corticosteroid administration. Vigorous medical treatment is now routinely undertaken pretransplantation in face of peptic ulcer disease.[2] Baseline bone surveys are done to permit long-term comparison studies on the effect of immunosuppressive drugs and to assess regression of underlying bone disease caused by renal and/or hepatic insufficiency. In children bone age films are also obtained.

In addition to these radiographic examinations that are ordered in potential recipients of all types of solid organ transplants, there are more specific tests that relate specifically to the type of proposed organ transplantation. Usually these are directed at answering specific clinical questions related to the appropriateness and technical feasibility of the transplantation procedure.

RECIPIENT ASSESSMENT

Radiographic Assessment of the Potential Renal Recipient.—Voiding cystourethrography is performed in potential renal recipients to exclude bladder abnormalities, urinary tract outflow obstruction, and vesicoureteral reflux.[1] If urinary tract outflow obstruction is present, be-

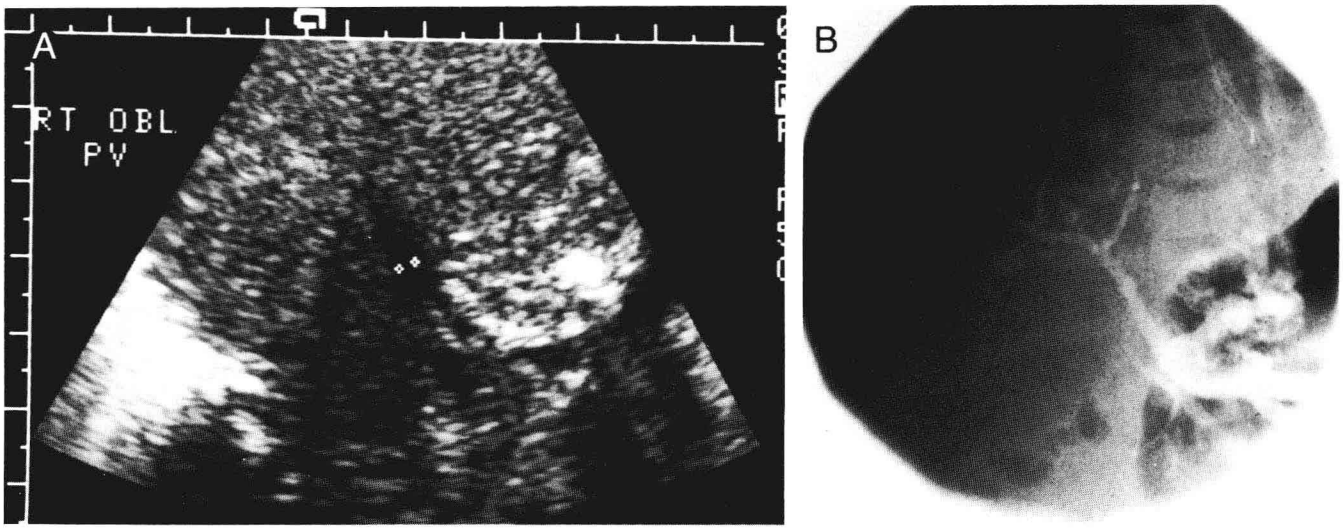

FIG 2–1.
Small, but patent, portal vein with size excluding liver transplant candidacy. **A,** sonography reveals an extremely small (2 mm), but main portal vein. Doppler examination verified its patency. **B,** splenoportography confirms the small nature of the portal vein and demonstrates numerous portosystemic collaterals.

cause of a congenital or acquired abnormality, repair of the obstruction is performed prior to renal transplantation. In patients with vesicoureteral reflux, pretransplantation bilateral nephrectomy and ureterectomy are performed. In children with complex urinary tract anomalies, urinary diversion or augmentation procedures may also need to be performed.[1] If the patient has already undergone urinary diversion with an ileal conduit, a loopogram is performed prior to renal transplantation. If reflux is present from the loop into the ureters or native kidneys, bilateral nephrectomy, ureterectomy, and resection of the ileal loop are recommended.

Radiographic Assessment of the Potential Hepatic Recipient.—Pretransplantation radiographic assessment of the potential hepatic recipient is specifically directed at determination of portal vein patency, the presence of potential vascular or gastrointestinal tract anomalies, the presence of portosystemic collaterals, and the diagnosis of potential bile duct malignancy. A vast array of noninvasive and invasive radiographic imaging modalities have been directed at this complex pretransplant assessment.[3–11]

Duplex sonography, with or without color flow capabilities, and CT are commonly used in the initial assessment of these patients.[5, 6, 9] Duplex sonography is helpful in determining patency of the portal vein, size of the portal vein, and direction of the blood flow within the splanchnic vasculature. A portal vein diameter of at least 4 mm is required for transplantation candidacy (Figs 2–1 and 2–2). Sonography with Doppler capabilities also provides capabilities of determining the presence of significant portosystemic collaterals and permits the noninvasive diagnosis of cavernous transformation of the portal vein.[7] Ambiguous studies will occur and complementary imaging with magnetic resonance and angiography is often necessary (see Fig 2–1). This is particularly true in the setting of slow portal venous flow, cavernous transformation of the portal vein, and complex vascular anomalies, most commonly seen in patients with biliary atresia.[7, 11–13] In cavernous transformation of the portal vein, partial recanalization of the portal vein or patency of small portal collaterals may be confused for a patent, small portal vein. Thrombosis of the portal vein usually precludes successful hepatic transplantation; consequently, if this diagnosis is suspected, confirmatory evidence with CT, magnetic reso-

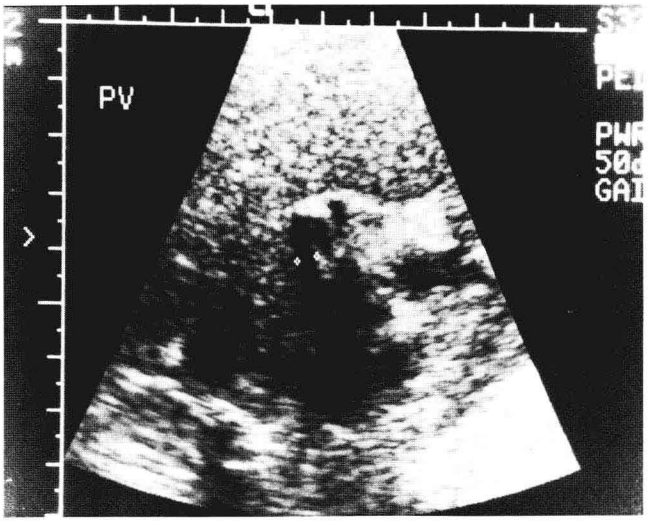

FIG 2–2.
Patent portal vein by transverse sonography in a pediatric liver transplant candidate. The vessel size is 4 mm in diameter, barely satisfying the minimum specifications.

FIG 2–3.
Widely patent portal vein *(arrow)* as seen by coronal MRI.

nance imaging (MRI), or angiography should be obtained.

When CT is done to determine portal vein patency, bolus intravenous contrast must be given and dynamic scanning techniques must be applied to the upper abdomen. MRI, although expensive, does permit examination of the portal venous system directly in a number of imaging planes (Figs 2–3 and 2–4).[12] Coronal and axial planes are most helpful in visualizing the portal venous system.

Angiographic techniques that can be utilized in hepatic transplant candidates include conventional or balloon-occlusion angiography of the celiac and superior mesenteric artery, wedged hepatic venography, direct transhepatic portal venography, and splenoportography (when polysplenia is not present) (see Figs 2–1 and 2–4).[3, 4, 10, 11] These angiographic techniques can be applied to both pediatric and adult candidates when noninvasive imaging is nondiagnostic.

Special circumstances of the pretransplant assessment of patients with extrahepatic biliary atresia need to be mentioned. These patients have a 10% incidence of associated congenital anomalies, including interruption of the inferior vena cava with azygous continuation, preduodenal portal vein, anomalous hepatic arterialization, intestinal malrotation, and polysplenia.[13] Pretransplantation identification of these anomalies, particularly the vascular anomalies, aids in planning the technical aspects of the transplant (Figs 2–5 and 2–6). In candidates with biliary atresia, MRI or angiography is recommended to include or exclude the possibility of vascular anomalies when it can-

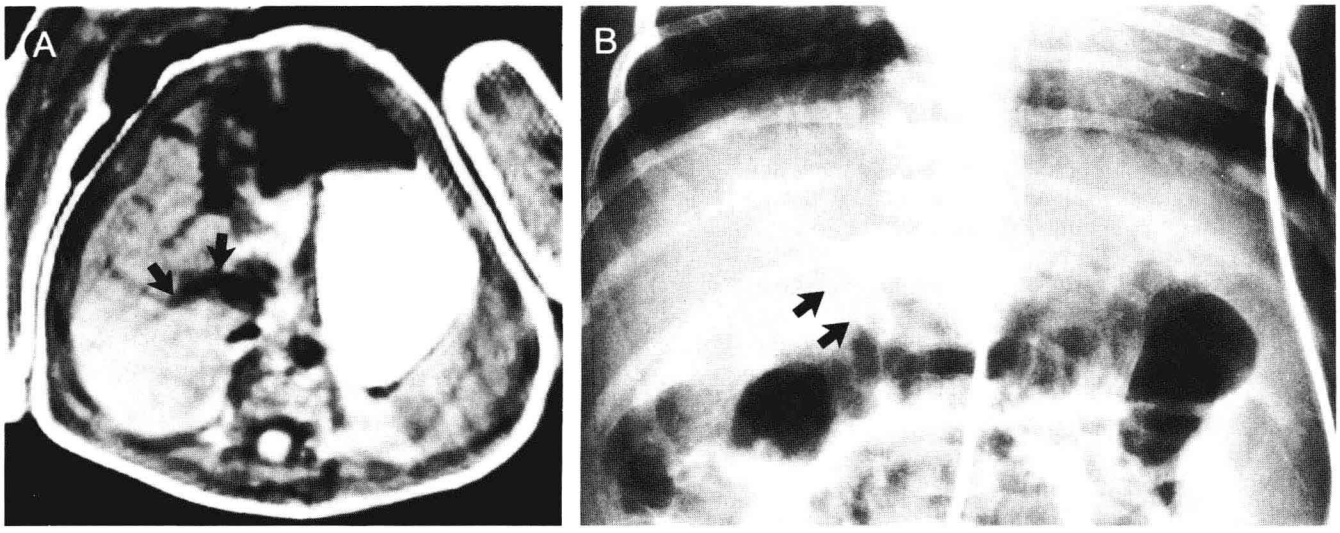

FIG 2–4.
Patent portal vein pretransplantation. **A,** axial MRI with T1-weighted images reveals a patent splenic vein. Although patent portal vein branches can be seen within the liver, an accurate measurement of the portal vein diameter cannot be made. **B,** aortography extended into the venous phase reveals faint opacification of a dilated portal vein *(arrows)*.

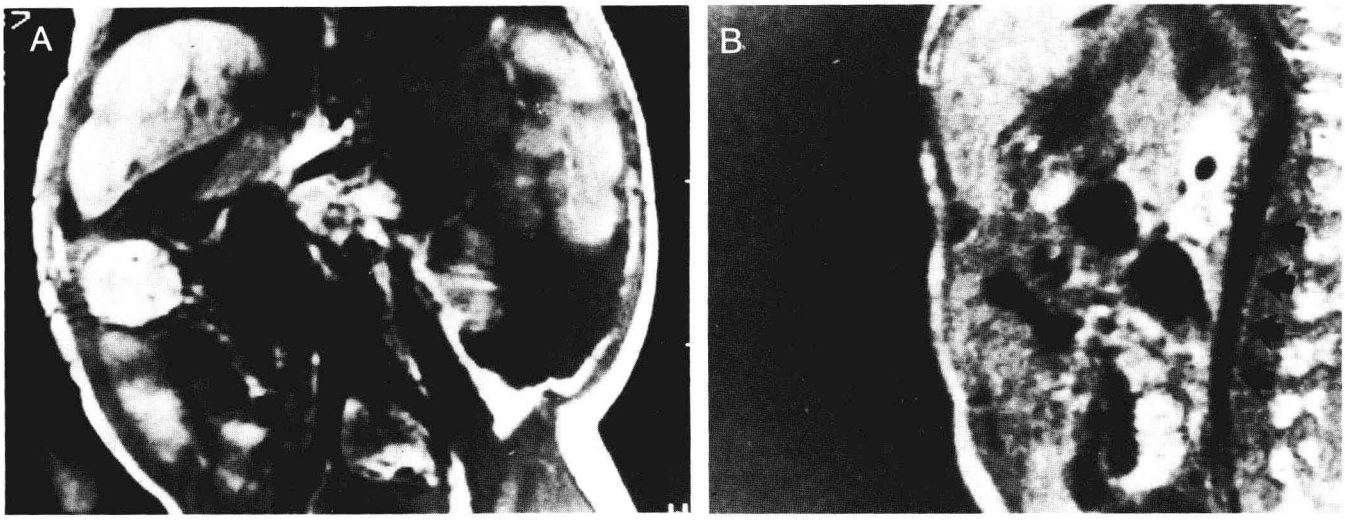

FIG 2–5.
A hepatic transplant candidate with biliary atresia also has polysplenia and azygous continuation of the inferior vena cava. **A,** polysplenia is seen by coronal MRI. **B,** sagittal MRI reveals azygous enlargement *(arrows)*.

not be determined with certainty if the inferior vena cava drains into the right atrium.

Patients with known or suspected sclerosing cholangitis who are candidates for hepatic transplantation should undergo diagnostic percutaneous or endoscopic retrograde cholangiography.[14, 15] Because of the increased incidence of cholangiocarcinoma in this patient population, all abnormalities suspicious for malignancy should be investigated further. This can be accomplished with intraductal brush or forceps biopsy once transhepatic access to the biliary tree has been obtained.[14, 15] Determination of the presence of bile duct malignancy is important, as patients transplanted with this underlying abnormality have markedly reduced graft and patient survival rates.[8]

Radiographic Assessment of the Potential Pancreas Recipient.—As pancreas transplantation is undertaken in patients with longstanding insulin-dependent diabetes mellitus, the incidence of peripheral vascular and coronary artery disease is potentially substantial in this group of transplant candidates.[16] Consequently, noninvasive duplex sonographic evaluation of the pelvic and lower extremity vessels may be obtained prior to transplantation to assess the suitability of the iliac vessels for graft vascularization and to assess the potential of limb ischemia after transplantation.

Silent coronary artery disease is common in diabetic patients; uremic pancreas transplants are evaluated for cardiac disease.[16–18] Noninvasive evaluation of cardiac function is begun with echocardiography and gated cardiac scintigraphy. If there is equivocal or definitive evidence of cardiac dysfunction that is possibly related to coronary artery disease, coronary angiography is performed prior to transplantation. Coronary angioplasty or coronary

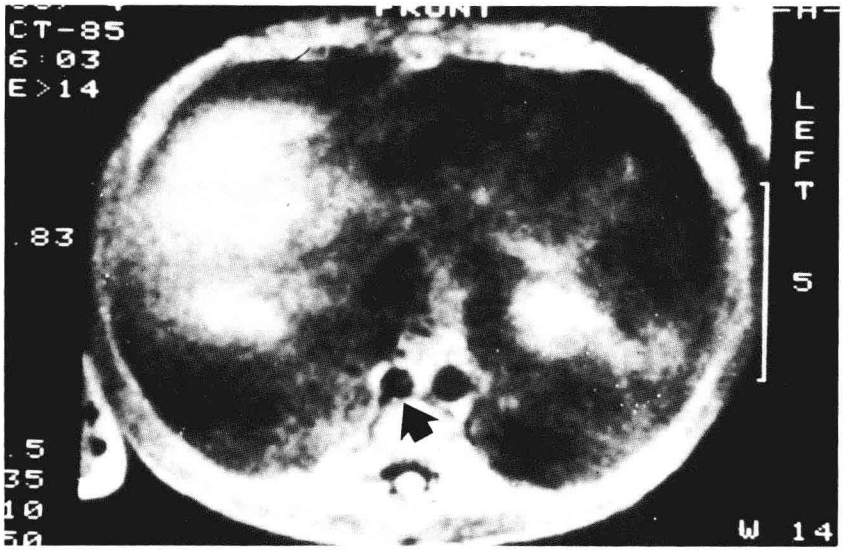

FIG 2–6.
Azygous continuation of the inferior vena cava in another child with extrahepatic biliary atresia. The enlarged azygous vein *(arrow)* is easily seen by axial MRI.