INTERVENTIONAL RADIOLOGY

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A Seminars in Roentgenology Reprint
January and April 1981

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GRUNE & STRATTON

A Subsidiary of Harcourt Brace Jovanovich, Publishers
NEW YORK LONDON TORONTO SYDNEY SAN FRANCISCO

The chapters of this book appeared originally in the January and April 1981 issues (Volume XVI, Numbers 1 and 2) of *Seminars in Roentgenology,* a quarterly journal published by Grune & Stratton, Inc., and edited by Benjamin Felson, M.D.

Grune & Stratton, Inc.
111 Fifth Avenue
New York, New York 10003

Distributed in the United Kingdom by
Academic Press Inc. (London) Ltd.
24/28 Oval Road, London NW 1

Library of Congress Catalog Number 81-82635
International Standard Book Number 0-8089-1414-6
Printed in the United States of America

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Contents

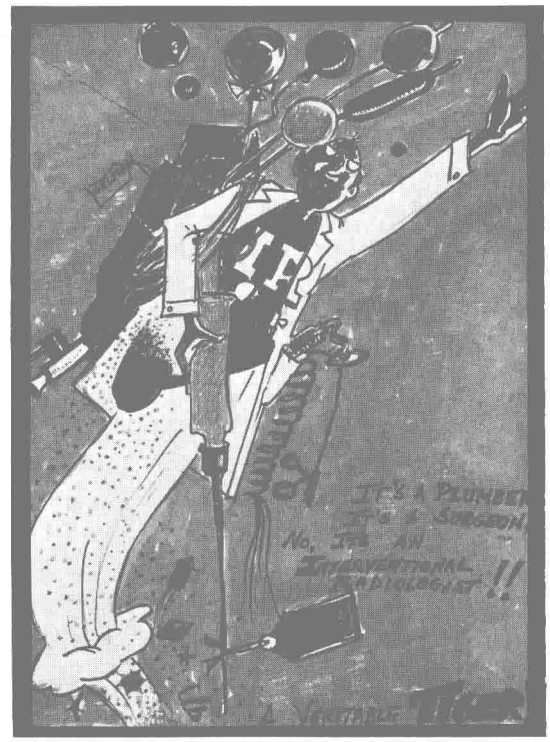
Letter from the Editor

THE TERM *interventional radiology* disturbs me. It seems to connote intrusion or interference, neither of which is a suitable word for the management of the sick. However, the radiologists in this new subspecialty appear to prefer this name. A subtle difference in terminology is often important. For example, in the production of ham and eggs, the hen is certainly *involved*, but the pig is totally *committed*. Since these radiologists are totally committed (the analogy stops there), they will doubtless be called interventionalists if that is their wish. Personally, I'd prefer some such term as *remedial radiology*. You don't like it? OK, invent a better one and I'll print it. Your prize will be a free coronary angioplasty by a remedial radiologist.

Our commitment to a *Seminar* on interventional radiology was already total when I discovered that Radiologic Clinics of North America, a publication I helped launch, had just published an issue on the subject. Our authors are different, the field is rapidly changing, and the subject is extensive (we had to spread it into two issues), so that the topic should still be timely.

Interventional radiology encompasses the use of a variety of radiologic modalities, including the various types of angiography, ultrasonography, radioisotope scanning, CT scanning, and even conventional radiography. And therein lies a rub. I have noted a curious phenomenon in these specialized divisions in many radiology departments that I have visited: the conventional radiographs are seldom carefully reviewed. What I mean to say is that the patient's previous films receive only perfunctory study before, during, or after the special procedure is performed and reported. Mistakes, serious ones, are made on this account alone. Often there are only a couple of 14 × 17 inch viewboxes available for this purpose in the ultrasound, radioisotope, or CT "read-out" room to study a thick jacket full of prior radiographs. To be sure, the chart and radiographic reports are reviewed, but this is not the same as personally examining the earlier films.

On comparing the current special study display with past conventional films, the abnormalities are often better recognized and interpreted. In fact, knowing from the new study



Cartoon drawn by Dr. Sidney Wallace.

where to look and what to suspect, the conventional films may now elucidate the true state of affairs. Furthermore, by correlating the conventional film findings with the display *during* the special study, valuable supplemental views and modifications of the procedure may be obtained before the patient leaves the department.

To pursue this point further, the clinician, in the interest of saving time and money, may not even bother to order conventional radiographic studies at all, but move immediately to special procedures. There are some situations in which this makes sense, but often this omission will prove detrimental to the patient. Appropriate conventional radiographic study may even make the special procedures unnecessary. I can show you many patients who have been subjected to a variety of special procedures, but in whom a more careful examination of the initial conventional radiographs would have made most, if not all, of these procedures superfluous.

There are no blanket rules for deciding when to omit conventional radiographic examinations, so that the approach in each patient must be

individualized. This decision should not be left entirely to the special procedurist, but rather should be a consensus opinion that includes input from the patient's clinicians. The same applies to the selection and sequencing of the special procedures. I find a strong tendency for each subspecialist to choose his own modality as the preferred one when the decision is his. Objectivity is only in the retinas of the detached! If we must speak of cost-effectiveness, we had better consider it from this standpoint as well.

This raises the question of the so-called *algorithm,* a word that will soon join *point in time* and *parameter* among the vintage clichés. It is the "in" term of the season and sounds as musical as *logarithm,* once defined as the ringing beat of the woodchopper's axe. An algorithm, originally a computation based on Arabic numbers, has come to mean a logical plan for the sequencing of a variety of procedures on the basis of differences in clinical findings among patients—a decision tree, as it were. I find the algorithm approach unsatisfactory because there are too many subtle imponderables to consider. Hence, the clinical findings and the judgment and experience of the clinician, radiologist, and subspecialists should form the basis of procedure selection in the individual patient. Rule of brain should supercede rule of thumb; a decision team is better than a decision tree. Cost-effectiveness should be a secondary consideration, not to be ignored but neither to be unduly weighted in the selection process.

Benjamin Felson, M.D.
Editor

GAMUT

Dilatation of Biliary Ducts (Extrahepatic, Intrahepatic)

Elizabeth S. Alexander and Sally E. Mitchell

COMMON

1. Carcinoma of pancreas, common duct, or ampulla
2. Gallstones, ductal
3. Chronic pancreatitis
4. Stricture (postsurgical, traumatic, or inflammatory)

UNCOMMON

1. Congenital
   - (A) Biliary atresia
   - (B) Caroli disease
   - (C) Choledochal cyst
   - (D) Diaphragm of hepatic duct
   - (E) Duodenal diverticulum (compression)
   - (F) Hepatic fibrosis with ductal ectasia
   - (G) Stricture
2. Inflammatory
   - (A) Duodenal ulcer, penetrating
   - (B) Liver abscess (including hydatid cyst)
   - (C) Mirizzi syndrome[2]
   - (D) Papillitis or fibrosis of sphincter of Oddi
   - (E) Parasites (clonorchiasis, fascioliasis, ascariasis)
   - (F) Sarcoidosis
   - (G) Sclerosing cholangitis, primary or secondary
3. Neoplasm, metastatic or other primary
4. Retroperitoneal fibrosis
5. Aneurysm of hepatic artery or aorta

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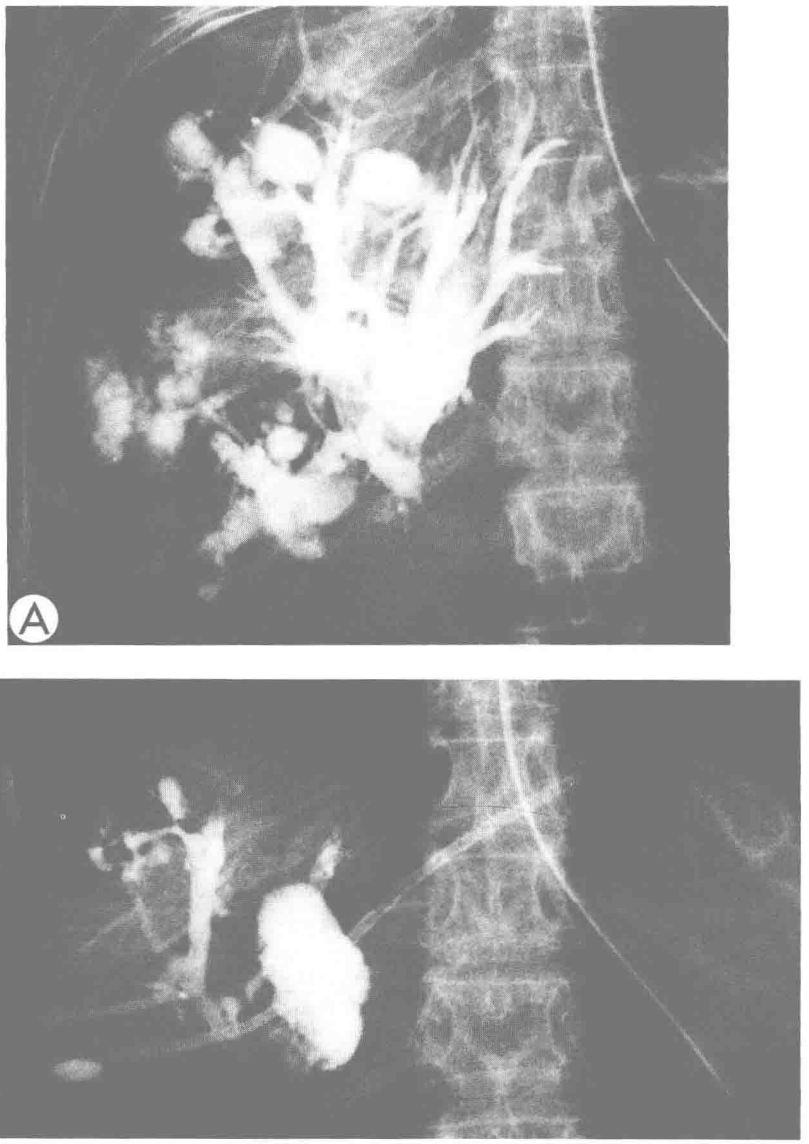

Fig. 1. Obstruction of the common bile duct by metastatic hypernephroma in the nodes at the porta hepatis complicated by multiple hepatic abscesses. The patient, a 53-yr-old woman with known hypernephroma and postoperative subphrenic abscess, had developed jaundice and sepsis. (A) Transhepatic cholangiogram shows multiple rounded cavities within the liver, filling from dilated intrahepatic radicles. There is no filling of the common bile duct beyond the porta hepatis. (B) Catheters have been placed in the right and left hepatic ducts for external drainage.

GAMUT

Unilateral Renal Lesion that May Result in Hypertension

Michael L. Streiter

1. Lesion of renal artery or its branches
   (A) Aneurysm
   (B) Arteritis (eg, syphilis, polyarteritis nodosa, thromboangiitis obliterans, rubella, idiopathic)
   (C) Atherosclerosis
   (D) Congenital narrowing
   (E) Dissection
   (F) Extrinsic compression by aortic aneurysm
   (G) Fibromuscular dysplasia
   (H) Fibrous or muscular bands (from crux of diaphragm or psoas muscle)
   (I) Neurofibromatosis
   (J) Perivascular fibrosis or subcapsular hemorrhage secondary to trauma
   (K) Thrombosis or embolism
2. Renal parenchymal disease
   (A) Cyst
   (B) Obstructive uropathy
   (C) Pyelonephritis
   (D) Radiation nephritis
   (E) Tumor (carcinoma, sarcoma, Wilms, metastatic)
3. Renal vein thrombosis
4. Ptosis of the kidney

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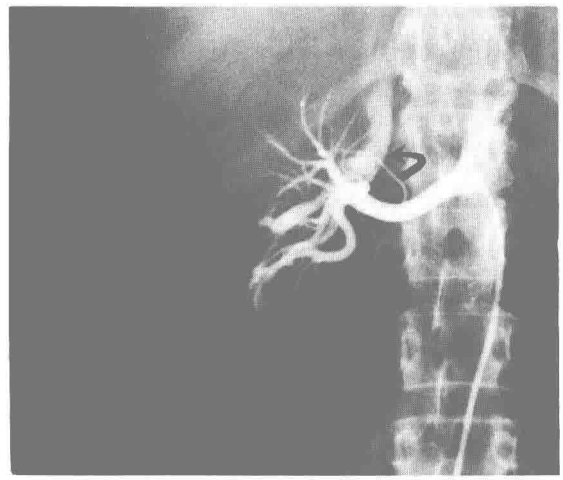

Fig. 1. A 35-yr-old female with high renin hypertension 3 mo following renal biopsy. Right renal arteriogram shows a pseudoaneurysm (straight arrow) and arteriovenous fistula with early filling of the renal vein and inferior vena cava (curved arrow).

Fig. 2. Arteriogram of the right lower pole artery, which supplies the arteriovenous fistula (arrow). Transcatheter embolization was performed in this position.

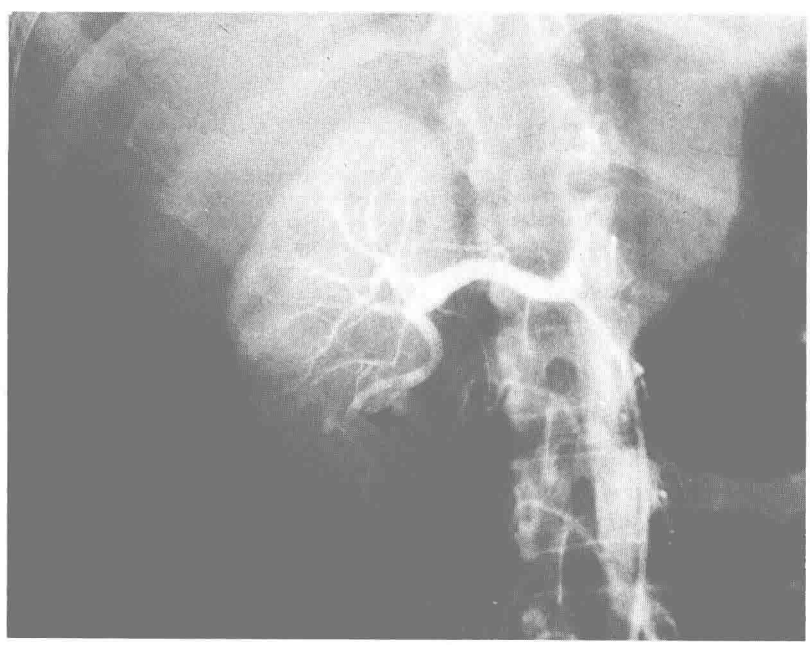

Fig. 3. Renal arteriogram following embolization shows complete occlusion of the arteriovenous fistula (arrow). The hypertension disappeared.

Interventional Radiology—Review of an Emerging Field

Charles T. Dotter

IN Southern California's Jet Propulsion Laboratory not long ago, a button was pushed—and 50 million miles away a man-made tool responded by digging a groove in the surface of Mars. At a less than interplanetary scope, in fact on an everyday basis, angiographers take advantage of a far simpler technology to plug bleeding arteries or open up dangerously narrowed ones within intact patients—intact except for minute skin punctures, portals of entry that permit catheter access to internal trouble spots.

Interventional radiology is an imperfect but useful term coined by Margulis to designate a recently emergent subspecialty of radiology dealing with a variety of percutaneous image-guided alternatives or aids to surgery. This review will focus on the things we do not only to understand, but also to treat our patients. A classic example of interventional radiology at its best is Porstmann's nonoperative closure of patent ductus, a safe and permanently effective procedure. Over 300 people have had their ductus closed with but two needle punctures in the groin, and no mortality and no recurrence, clearly a better way to treat this lesion.

Interventional radiology got its start in the early 1960s. Before this, urologists had made good use of catheters, and neurosurgeons had evidenced interest in catheter embolization of intracranial aneurysms. Percutaneous transluminal angioplasty, a completely radiologic procedure, began in 1964 with dilation of a localized arterial stenosis in the leg of an 83-yr-old woman who had refused amputation for gangrene. Skeptical surgical colleagues kept her in the hospital under observation for several weeks, expecting the dilated artery to thrombose. Instead, her pain stopped, she started walking, and three irreversibly gangrenous toes spontaneously sloughed off sans scalpel. The dilated artery stayed open until her death 3 yr later.

While to me professional acceptance of this simple alternative to vascular surgery seemed painfully slow, other innovators in the field of interventional radiology did better. Surgeons welcomed the retrieval by radiologists of tubing fragments lodged in the cardiovascular system and gallstones remaining after cholecystectomy.

Interventional radiology underwent near exponential growth in the 1970's, with major impetus coming from better tools, techniques, and image monitoring systems. Acceptance ultimately came, both for catheter revascularization and its converse, therapeutic vascular occlusion. There now follows an incomplete, at times biased, review of the still-expanding field of interventional radiology, with a speculative look at its future.

A needle or catheter system may play either or both of two fundamental roles in treatment. First, it may be used as a primary tool for mechanically attacking a lesion (as in transluminal angioplasty), for retrieval of a foreign body or gallstone, or for drainage of an obstructed bile duct, renal collecting system, or abscess. Secondly, it may be used for the selective delivery of a drug, occlusive material, or device to a specific target for a wide variety of clinical purposes. At present, the most active area of interventional radiology is in the controlled therapeutic production of vascular occlusion.

VASCULAR OCCLUSIVE THERAPY

There are many ways by which the interventional radiologist can produce selective partial or complete, temporary or permanent ischemia. Probably the first of these was Newton's embolization of a spinal angioma in 1968. In the following year, selective infusion of vasoconstricting drugs to control gastrointestinal (GI) bleeding was performed. This proved more effective in arteriocapillary bleeding caused by gastritis, mucosal tear, stress ulcer, and colonic diverticulosis than in bleeding from chronic peptic ulcer with erosion into a relatively large artery.

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Although progress in endoscopy has relieved the angiographer of a primary role in the emergency diagnosis and management of acute GI bleeding, he is still called upon, though less often at night.

Severe hemorrhage into the GI tract in association with trauma, tumor, surgical complications, or nosebleed can ordinarily be stopped by transcatheter embolization of the bleeding artery. The first embolization for GI bleeding was reported in 1972 by Rösch, who injected autologous blood clot into the gastroepiploic artery, successfully arresting a previously intractable hemorrhage from a greater curvature gastric ulcer.

To date, many substances have been delivered through catheters in the production of arterial occlusion at various desired (and a few undesired) sites. Thrombin-induced and Amicar-fortified clots, bits of muscle or fat, Oxycel, and Gelfoam, in pieces of various sizes and shapes, mixed with contrast agents, have been used to cause arterial occlusions of varying durability. Where permanent occlusion was sought, Ivalon (polyvinyl foam) has been used, either in fragments or, as first attempted in 1967 by Porstmann, in the form of compressed plugs that expand after placement. Silicone spheres, rapidly polymerizing silicone rubber, isobutyl 2-cyanoacrylate (a rapidly polymerizing bioadhesive), and all manner of balloons, some detachable, have been used. Gianturco's coilspring occluders are widely employed catheter-delivered permanent intraluminal hemostatic devices. White has reported on detachable balloons distended with iso-osmotic contrast agent and deposited where needed. Opinions differ as to which of these materials is best for what. The state of the art—let's call it a science—continues to evolve.

Currently, active interest in vascular occlusive therapy reflects the many purposes it can serve. At least 149 reports were published in 1979 on the subject. Selective embolization can control nosebleeds at one end of the patient and no doubt bleeding hemorrhoids at the other (not yet reported, to my knowledge).

When improperly used, vascular occlusion may be the opposite of therapeutic. Most of the GI tract is supplied with adequate collaterals, but there is a net loss to the patient if bleeding from an ulcer is stopped at the cost of infarction. Splenic arterial embolism may result in splenic abscess instead of the desired "medical splenectomy." Inadvertent misplacement or reflux of embolic material intended for a renal artery has led to the loss of a foot. Where hemostasis is the object, it is mandatory that the delivery catheter be placed superselectively into the bleeding artery. Care, technical skill, knowledge, and clinical responsibility are critical to the safety and effectiveness of this form of therapy. Properly used, it may add greatly to the management of tumors from head to toe. Therapeutic organ ablation, as with protein-losing kidneys in dialyzed transplant candidates, may be achieved: adrenal, thyroid, and even parathyroid glands are subject to embolic tranquilization.

Management of congenital arteriovenous malformations is an important area effectiveness. Postbiopsy renal or other arteriovenous (AV) fistulas are readily cured by superselective luminal obliteration. Spermatic vein occlusion has cured varicocele. The preoperative occlusion of arteries supplying a hypervascular tumor, such as an angiofibroma or renal neoplasm, may make a lifelong friend of the surgeon.

Selective transhepatic or transjugular portal catheterization with occlusion of varices and their feeder veins is of value in the control of life-threatening bleeding gastroesophageal varices. All hazardous shunts must be located and occluded while nonhazardous shunts are preserved. Through the successful obliteration of varices, portal flow is denied an important, if dangerous, escape route. Increasing portal hypertension may lead to the development of other variceal feeders and rebleeding in a matter of weeks or months in a significant number of patients so treated. The nonoperative transjugular creation of intrahepatic portosystemic shunts, first done by Rösch in dogs over a decade ago, is under renewed investigation in our animal laboratory. When we learn to make shunts that will remain open long enough to be clinically useful, there will be ample opportunity to take the long step between the experimental laboratory and the angiography room. On the same subject, if not in a similar vein, selective vasopressin infusions into the superior mesenteric artery were for a time used to reduce portal flow and thereby decrease pressure and variceal bleeding. However, it was found in our dog

laboratory that similar doses given intravenously did about as well. Here again, the primary management of acute GI bleeding, in this case variceal, has reverted to the gastroenterologist. We still do transhepatic embolization for variceal bleeding, but less often on an emergency basis. We consider prophylactic variceal obliteration a valuable technique and are not in full agreement with the recently reported hesitancy of Lunderquist, who introduced it.

TRANSLUMINAL ANGIOPLASTY

Although the most active area of interventional radiology deals with the deliberate occlusion of blood vessel, another increasingly active area lies in exactly the opposite direction—the treatment of ischemia caused by arterial obstruction.

Since 1964, I have performed transluminal angioplasty in over 600 patients. My results are in general agreement with those reported by Zeitler, Porstmann, van Andel, Grüntzig, and others. Simple stenoses in the iliac and femoropopliteal arteries can be dilated successfully in about 85%, with perhaps 1 in 5 requiring redilation in 1 or 2 yr. The arterial occlusion must be traversed or recanalized to create a dilatable neolumen. Short complete occlusions (forgive the redundancy) respond almost as well as stenoses; longer occlusions carry a poorer prognosis for both immediate and lasting success. Nevertheless, even these are suitable for transluminal recanalization if surgery is unavailable, refused, contraindicated, or has failed. Leg amputation for ischemia bears a mortality of up to 20%, depending on the quality of surgical care and the patient's ability to withstand its trauma.

Balloon catheters are now in general use for transluminal angioplasty. For obvious reasons, they have always been essential for iliac dilation. The first iliac artery was dilated using a Fogarty balloon catheter over 14 yr ago. The artery remains open today, and the patient still has the good femoral pulse he regained so long ago. Caged balloon catheters (referred to as "Korset-balloons" by Porstmann, their originator) have served well in treating many stenotic iliac arteries, but were deservedly put into limbo by Grüntzig's development of an ingenious double-lumen catheter bearing a strong-walled polyvinyl balloon suitable for insertion and advancement over a wire guide. Thanks to this basic design, small, flexible balloon catheters can be used in branch arteries, such as the renal and coronary, while larger ones can be inserted in one femoral artery, and passed over the aortic bifurcation and down into the other, to treat arteries on both sides. I still use coaxial or tapered Teflon dilating catheters for most downstream femoropopliteal lesions—perhaps be-

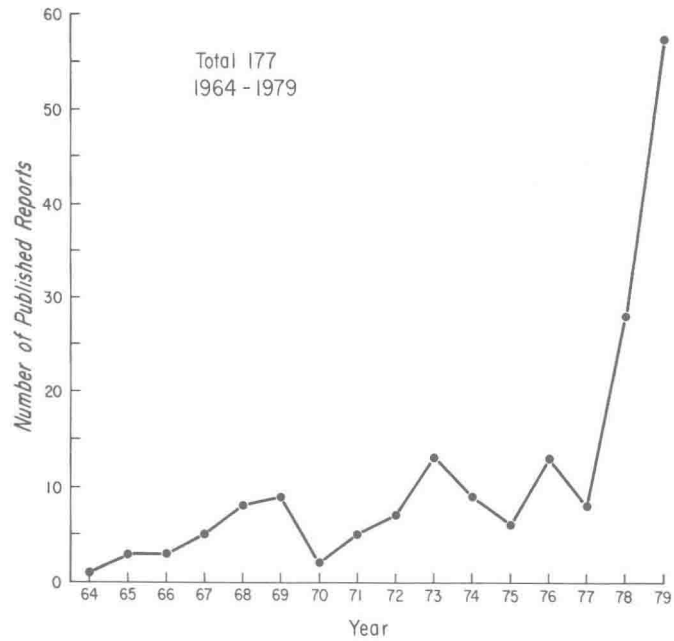

Fig. 1. Published reports on transluminal angioplasty.

cause they work well and rapidly for me, perhaps because I'm just used to them. Instead of using specified balloon pressures to control iliac dilation, I rely on the balloon's fluoroscopic appearance and resistance to movement as guides to the degree of distention best suited to the individual circumstance. A balloon or an artery has yet to burst in the process.

Transluminal angioplasty was for 10 yr looked upon as something of a pariah in this country, if not in Europe. The impetus afforded by Grüntzig's new catheter is dramatically shown in Fig. 1, which presents by year the number of published reports on transluminal angioplasty. Equipment sales indicate that more than 10,000 procedures were probably done last year alone.

RADIOLOGICALLY ORIENTED BILIARY TRACT THERAPY

The postoperative T-tube tract provided a portal for the radiologist's therapeutic entry into the depths of the biliary ducts. His intrusion was welcomed in that its purpose was the nonoperative disposal of gallstones retained following cholecystectomy. Various fluoroscopically guided means have been used to push, pull, or otherwise get the rocks out. Best known and most widely adopted is Burhenne's application of a steerable catheter/stone basket combination. Although thousands of gallstones have been removed with few complications, efforts can be frustrating, and even in skilled hands multiple sessions are often required. Promising techniques for physically pulverizing or chemically dissolving biliary calculi are under investigation. The T-tube tract is no longer the only alternative to reoperation, for gallstones have been removed via the percutaneous transhepatic route, and endoscopic sphincterotomy has provided yet another workable approach. I hope that in time the removal of all gallstones—not just those left behind—will no longer be primarily a surgical matter.

The development of percutaneous fine needle transhepatic cholangiography soon led to ductal catheterization and new nonsurgical means for the management of biliary obstruction caused by tumor, postsurgical, or other strictures. Transhepatic catheters can provide internal or external, temporary or long-term biliary drainage, minimizing the threat of sepsis and palliating the course of inoperable malignant tumors. Catheters can be used to dilate anastomotic and other non-neoplastic ductal narrowings.

PERCUTANEOUS UPPER URINARY TRACT TREATMENT

Percutaneous, nonsurgical access to the upper urinary tracts dates back to Wickbom's description of antegrade pyelography in 1944. A big assist was derived from Goodwin's 1955 report on percutaneous nephrostomy. Since these early beginnings, the use of angiographic techniques, image intensification videofluoroscopy, and ultrasound and CT guidance has led to increasing reliance on percutaneous therapeutic techniques in patients in whom surgery might otherwise be needed. Among these are those requiring temporary or long-term drainage for hydronephrosis, sepsis, or renal failure due to obstruction lower down in the urinary tract. Kidney stones have been removed, ureters have been dilated, and ureteral stents placed via the percutaneous approach. The method has been extended to the management of obstructed renal transplants. Serious procedural complications, such as perinephric abscess or hemorrhage are rare; the relatively minor problems posed by catheter displacement and obstruction may be minimized by tract dilation and the use of larger self-retaining catheters.

RETRIEVAL OF FOREIGN BODIES

Percutaneous techniques for the retrieval of catheter-accessible foreign bodies, especially fragments of tubing embolically lodged in the right heart or pulmonary arteries, are now in general use. The number of different tools and techniques rivals the number of published case reports on the subject. As reported by Bilbao et al, the fluoroscopically guided intestinal catheterization techniques adapted from those of the angiographer may be used to grasp and remove foreign bodies hung up beyond the reach of the endoscopist.

SELECTIVE DRUG AND RADIOISOTOPE THERAPY

The delivery of maximal safe therapeutic doses of cytotoxic or radioactive agents directly into a tumor or region of metastatic involvement is favored by selective intraarterial administra-

tion. This is at times done preoperatively to diminish the size and facilitate the resection of a large tumor. More often this approach is used for palliation of an inoperable tumor. Transfemoral catheters are used for short term treatment, while small transbrachial or transaxillary catheters allow patient mobility and may be left in place for weeks or months. The temporary or permanent occlusion of competing collateral arteries is a desirable adjunct to the catheter perfusion of hepatic metastases. The selective delivery of drugs is also useful in nonneoplastic conditions. Vasoconstrictors in the control of bleeding have already been mentioned. Short or long term vasodilators may be similarly administered to treat vasospastic ischemia at various sites, including the heart, brain, GI tract, and extremities.

SELECTIVE CLOT LYSIS

Fresh clots within the vascular system can be dissolved by the systemic use of potent fibrinolytic agents such as streptokinase and urokinase. The dissolution of useful as well as offending clots has caused hemorrhagic complications at recent puncture sites or surgical incisions, lessening enthusiasm for the approach. By the transcatheter selective administration of the fibrinolytic agent just above or directly into systemic arterial clots, we have effected their dissolution at markedly reduced dosage and with fewer hemorrhagic complications. It is hoped that through selective infusion into mesenteric arteries or even more directly delivered via portal vein catheterization, the early use of fibrinolytic agents may provide a much needed therapeutic method for the treatment of acute portal vein thrombosis in infants as well as adults. To date, this logical method of preventing later variceal hemorrhage remains untried.

PERCUTANEOUS EMBOLECTOMY

Catheters, steerable and otherwise, have already been used in a few reported instances to extract emboli from both pulmonary and systemic arteries. Difficulty in extracting a large pulmonary embolus with a small catheter is obvious. On the other hand, the fragmentation or dislodgment of a life-threatening centrally occluding clot in the pulmonary arteries has merit in that it allows flow through at least some peripheral branches, reducing overall pulmonary resistance and right ventricular overloading. This is more than hypothetically attractive; in one of our patients, it was followed by immediate hemodynamic and clinical improvement. Such an approach is not suitable for use in systemic arteries, where the more distal displacement of thrombi could make them inaccessible to surgical or other retrieval, while worsening matters by the occlusion of essential end-arteries.

CYST AND ABSCESS DRAINAGE

As with percutaneous needle biopsy of internal lesions, deeply situated cysts and abscesses can now be entered by the interventional radiologist with precision and therapeutic as well as diagnostic advantage. Following the informative aspiration of their contents, agents such as alcohol or Pantopaque are said to favor the regression of renal cysts. Similarly, percutaneous drainage, irrigation, and instillation of antibiotics into an abscess may aid, and at times replace, surgical management.

CATHETER INTERVENTION IN THE INFERIOR VENA CAVA

Mobin-Uddin's umbrella filter for the inferior vena cava has had considerable use for the prevention of pulmonary embolization. It is usually positioned from above via cutdown in the external jugular vein. Simon and colleagues in 1977 reported their experimental use of nitinol wire to accomplish this percutaneously. Balloons have been used to produce both temporary and permanent occlusion of the inferior vena cava. In my opinion, deliberate permanent caval interruption is a bad choice among evils, since it causes significant lifelong problems in the lower extremities. It is hoped that fibrinolytic drugs will in time reduce or abolish the occasional need for prophylactic permanent vena caval occlusion, surgical or otherwise.

PERCUTANEOUS CLOSURE OF PATENT DUCTUS ARTERIOSUS AND OTHER CONGENITAL DEFECTS

The Porstmann technique, originally described in 1967, has been successfully and safely used in hundreds of patients, principally by its originator and in Japan. I am aware of but one reported application, and only to a few patients

in the U.S., surprising in view of its relative safety and effectiveness compared to that of surgical closure. King, in this country, has described a transvascular technique employing interlocking umbrellas, which by 1978 he had successfully used to close an atrial septal defect in five patients.

BLUE-SKY SPECULATIONS ON THE FUTURE OF INTERVENTIONAL RADIOLOGY

This review of the therapeutic accomplishments made possible through relatively noninvasive, guided percutaneous access to trouble spots within the intact patient has been at times speculative in content. What of the future? Pragmatically speaking, radiologic special procedures tend not to be as cost-effective as routine diagnostic studies, where the image is the object. Innovation will surely lead to the development and therapeutic use of yet unthought of techniques and instruments. I recall in 1949 asking the only manufacturer of vascular catheters to help in the design and construction of balloon catheters and a catheter valvulotome for congenital pulmonary valvular stenoses. I got the balloon catheter, but no response whatever to the other request. Such a catheter might have worked—it still might.

Other possibilities seem more feasible. A catheter tip that can be changed intraluminally to assume a flared or funnel configuration would permit extraction of clots from blood vessels by a percutaneous application of Fogarty's approach. A guide tipped with a debris-capturing helicoid cutter designed and given to me by Gianturco awaits an opportunity to use it for endarterectomy in a patient scheduled for leg amputation. Its only clinical application thus far has been the successful cleaning out of an otherwise hopelessly clogged soft rubber biliary drainage tube. There is reason to hope that something like it will play a similar but more important role in the vascular system.

Mention has already been made of Rösch's proposal to create intrahepatic shunts between the portal and systemic venous systems, as a percutaneous alternative to high mortality surgical shunting for the decompression of life-threatening portal hypertension in cirrhosis. To prevent the prompt thrombosis of such shunts, it seems likely that tissue removal (as opposed to simple dilation) will be needed to obtain adequate caliber. We have designed and will soon use in experimental animals a catheter based on the commercially available Cryoprobe. By the decompression of liquid nitrogen in a 1 cm long metal cylinder at its tip, we hope to literally freeze away a cylinder of hepatic tissue, thereby achieving a shunt of large enough caliber to allow long term patency.

Vessels can be punctured from inside out, thereby providing controlled egress into surrounding tissues and, if desired, outward through the skin at desired locations. Catheters can be used for transhepatic transductal sphincterotomy. They can also be used to obliterate arterial dissections and pseudoaneurysms. Perhaps superselective prostatic infarction or pharmacotherapy may provide a means of reducing the effects of benign prostatic hypertrophy.

Catheter grafting deserves further study, I believe. In 1969, I reported on transluminally placed open coilspring "sleeve" grafts in dog femoral arteries, with angiographically proved patency at 2.5 yr. Sparks' method for "growing" femoropopliteal bypass grafts around surgically placed and subsequently removed mandrils suggests the feasibility of a transluminal catheter counterpart. Catheter-placed devices have met clinical success in the closure of patent ductus and atrial septal defect. Why not catheter-placed prosthetic valves? Femoral vein valve incompetence might offer a reasonable initial target. Other simpler means might pay off in a percutaneous catheter treatment for varicose veins, even hemorrhoids.

Though prospects for catheter gastrectomy seem dim, other alternatives to surgery are not. The two most common major operations currently done in our country are said to be cholecystectomy and coronary artery bypass grafting. With luck and ingenuity, it may be that less invasive image-guided techniques will some day supplant or at least reduce the need for both. The subsurface visibility provided by present and future medical imaging offers an essential ingredient to progress in this direction, both a challenge and an opportunity to the interventional radiologist. *Sic transit gloria scalpellorum!*