Percutaneous transluminal coronary angioplasty

A review of the literature

J. Z. PRZYBOJEWSKI, H. F. H. WEICH

Atherosclerosis is accepted as being a most important disease process which gives rise to varying clinical presentations depending upon the part of the vascular system most affected. Thus, involvement of the head and neck vessels, as well as the cerebral arteries, can result in a cerebrovascular accident of varying intensity; abdominal aortic involvement often terminates in aneurysm formation with its sequelae; mesenteric artery involvement presents with gastro-intestinal symptoms, such as 'mesenteric angina'; renal artery disease, particularly at the origins from the abdominal aorta, can express itself in the form of hypertension and varying degrees of renal decompensation; involvement of the lower limb vasculature classically presents with intermittent claudication or 'peripheral vascular disease'; and coronary artery atherosclerosis results in the spectrum of ischaemic heart disease (IHD) as represented by the anginal syndromes and acute myocardial infarction. Symptomatic relief, particularly with the disease process involving the coronary arteries and peripheral vascular disease, was achieved by the classic operations employing some form of 'bypass' of the obstructed artery segment. Thus, such palliative procedures as aorto-iliac, iliofemoral and aortocoronary bypass were introduced as part of the surgical management of these common clinical expressions of atherosclerosis. These operations often resulted in a dramatic amelioration or actual disappearance of the debilitating symptoms of intermittent claudication and angina pectoris, albeit only temporarily.

A revolutionary non-invasive or non-operative approach to atherosclerotic obstruction was first introduced on 16 January 1964 by Dotter and Judkins.[1] These pioneers described the technique of 'transluminal recanalization' of peripheral lower limb arteries employing a Teflon dilatation catheter (Cook Inc.) inserted percutaneously into the contralateral femoral artery by the Seldinger technique. This procedure soon became known as 'transluminal angioplasty'. Nevertheless, this intervention resulted in frequent thrombotic and haemorrhagic complications which led Andreas Grüntzig, a Swiss radiologist working in Zurich, to design and introduce, in 1974, a unique double-lumen polyvinyl balloon catheter with non-elastic properties.[2,3] This modification made for a far more successful procedure.[4-6] Consequent upon this successful technical modification for use in peripheral vascular disease, Grüntzig, in 1976, developed a much smaller balloon dilatation catheter for use in coronary artery disease.[7] Further extensive research work[8-10] utilizing surgically created coronary artery obstruction in canine and human cadaver hearts, as well as intra-operative experimentation during coronary artery bypass surgery, led Grüntzig to perform the first successful human percutaneous transluminal coronary angioplasty (PTCA) in Zurich on 16 September 1977.[11] He then continued to carry out this procedure in a large series of patients in Switzerland[12] prior to its employment in the USA in 1978.[13-16]

The purpose of this article is to review PTCA, which can be considered to be a truly revolutionary and fairly simple non-invasive form of intervention.[17-20] Furthermore, the 'epidemic' of IHD in the RSA calls for the employment of this technique, which has already been carried out in a few teaching hospitals in this country. Very recently, modified balloon dilatation catheters have been used percutaneously in the non-operative transluminal correction of congenital coarctation of the aorta in infants and children,[21-23] congenital pulmonary valve stenosis ('valvuloplasty'),[24,25] and hypoplasia and stenosis of the pulmonary arteries.[26,27] It has also been employed for PTCA and for the simultaneous occlusion of coronary-bronchial artery anastomosis using a detachable balloon.[28]

Cardiac Clinic, Department of Internal Medicine, University of Stellenbosch and Tygerberg Hospital, Parowvallei, CP
J. Z. PRZYBOJEWSKI, M.B. CH.B., F.C.P. (S.A.)
H. F. H. WEICH, B.SC., M.ENG. (CIV.), M.B. CH.B., M.MED (INT.MED.), M.D.

Equipment

Cine angiographic and video component

Highly sophisticated cardiac catheterization equipment has to be available before any attempt is made to carry out PTCA.[29-31] The fact that superb quality coronary cine angiograms are produced by a catheterization laboratory is not necessarily indicative of suitability to carry out PTCA, since one of the most essential components of the apparatus, a high-resolution video imaging system, is often lacking in laboratories performing routine cardiac catheterization and selective coronary cine angiography.[32] Facilities should be available for obtaining cranial and caudal angulations in addition to the more routine lateral and oblique projections. This can be achieved by a C-arm cine angiographic system. The ideal cine angiographic apparatus appears to be a biplane C-arm,[32] and some centres even utilize a biplane isocentric set-up.[33] For proper visualization of the obstructive coronary lesions magnification with 12,5 cm or 15 cm image intensifiers, as opposed to the 22,5 cm or 25 cm image intensifiers employed for routine cardiac cine angiography, is mandatory. With increasing magnification resolution of the image usually deteriorates but this is counteracted by using a caesium iodide tube. Electronic magnification increases the radiation dose and thus increases the danger of radiation to the operators, technical and nursing staff, as well as to the patient. Prolonged fluoroscopy is often inevitable in difficult PTCA cases, but this can be diminished by the availability of a sophisticated video imaging system. The quality of the video component is just as important as that of the cine angiographic one, since correct placement of the dilatation balloon catheter over the lesion is crucial as is accurate visualization on replay to determine whether dilatation has been angiographically successful.

Catheter component

This is a coaxial catheter system and basically consists of two catheters — the guiding catheter and the dilatation catheter (also sometimes referred to as the 'balloon catheter' or 'balloon dilatation catheter'). The guiding catheters are radiopaque and Teflon-coated and have an external diameter of French 8 - 9. They have a greater internal diameter when compared with the standard coronary angiographic catheters and possess Amplatz or Judkins curves of varying size. In addition, these guiding

catheter curves can either be 'in-plane' or 'out-of-plane' with respect to the main shaft of the catheter. This allows for greater flexibility as regards the aortic arch configuration and location of the coronary artery ostium. There are several guiding catheters available such as the Grüntzig Dilaca manufactured by Schneider Medintag AG; the Myler femoral guiding catheter; USCI Grüntzig Dilaca catheters; the Simpson-Robert Vascular Dilatation System (Advanced Catheter Systems Inc.); and Stertzer brachial guiding catheters.

The Teflon-coated dilatation catheters are much more intricate and smaller, having an external diameter of French 4 - 4,5, since they have to be passed through the guiding catheters. A vital component of the dilatation catheter is the balloon, which is manufactured either from polyvinyl chloride or irradiated polyolefin. These balloons come in lengths varying between 1,2 and 2,0 cm, the proximal and distal ends being delineated by radiopaque markers sometimes made of gold. The balloons are also obtainable with a post-inflation diameter varying between 2,0 and 3,7 mm. An important characteristic of the balloon is its ability to enlarge to a fixed diameter, thus diminishing the possibility of the transmission of excessively high and dangerous pressure to the coronary artery wall. The dilatation catheter has a double lumen: one lumen is positioned at the tip of the catheter to allow for passage of a guidewire and measurement of intracoronary pressure and injection of contrast media; the other lumen communicates with the balloon to permit the injection of diluted contrast medium for inflation or deflation. The original dilatation catheter employed by Grüntzig[12] (Schneider) had a soft 5 mm long wire fixed to the distal end of the balloon so as to avoid any possible injury to the coronary artery wall as well as to help direct the catheter. Nevertheless, this guidewire was not 'steerable' in the strict sense of the term. During the last year 'steerable' guidewires which are Teflon-coated and have flexible tips have been introduced,[34,35] and according to Grüntzig (personal communication) this innovation has increased the 'primary success rate' of PTCA.[36] These steerable guidewires are not connected to the dilatation catheter and can, on account of their manufacturing design, be directed from the proximal operator-end. A unique feature of these guidewires is that their stiffness diminishes gradually towards the distal tip. Some of these are gold-coated over the distal few centimetres to improve radiopacity.

The remainder of the catheter component to be considered is the mode of inflation and deflation of the balloon attached to the dilatation catheter. In Grüntzig's[12] initial description of the method a 'calibrated pressure pump' (Schneider) was utilized to inject a saline/contrast medium mixture in a ratio which varied from 50:50 to as high as 70:30. Some workers employ a hand-held device regulated by a pressure dial.[34,35,37] Not long ago the Dorros spring pressurizer[38] was introduced, which is an ingenious device utilizing a calibrated spring controlled by the rotation of a screw. Other workers have recommended the use of a two-way stopcock positioned between the hand-held inflating syringe and balloon port of the dilatation catheter which allows for constant pressure application and relieves the operator.[39]

A most recent innovation has been the introduction of a double dilatation catheter allowing for the simultaneous correction of serial coronary stenoses. This new addition to the equipment range employed in PTCA will broaden the indications for this procedure, as well as curtail the time taken to perform it.

Technique

Assessment of coronary cine angiograms

Prior to any attempt at PTCA the selective coronary cine angiograms obtained during previous cardiac catheterization should have been meticulously reviewed by the cardiological unit to assess the feasibility or otherwise of the procedure (parameters determining this decision will be discussed later). These cine angiograms must then be critically scrutinized in consultation with the cardiothoracic surgical team so as to obtain a consensus as to whether the procedure is preferable to the more conventional aortocoronary bypass graft operation. Furthermore, the patient's coronary anatomy must lend itself to such a bypass procedure.[40-42] This combined consultation is especially important to ensure the surgical team's preparedness and willingness to embark on emergency or elective aortocoronary bypass surgery in the event of complications arising from PTCA. It is most unusual for PTCA to be carried out at the same sitting as routine selective coronary cine angiography, since the suitability or otherwise of this procedure in a particular patient cannot be predetermined.[43-45] Furthermore, adequate evaluation of the coronary cine angiograms is not possible in the time available; assessment then must be based on videotape replay recordings rather than on processed film; the patient is not prepared for the procedure; and the surgical team is not always available on emergency standby. The cardiologists responsible for carrying out PTCA must measure the dimensions of the coronary artery stenosis and proximal and distal parts of the coronary artery from selective coronary cine angiograms in order to know what size of balloon dilatation catheter to utilize. At Tygerberg Hospital some cut films are also taken of the 35 mm cine-angiographic still frames in several projections and these plates are displayed on the viewing screen in the cardiac catheterization laboratory during PTCA.

Medication prior to PTCA

Fully informed consent is mandatory and the patient must agree to aortocoronary bypass surgery or any other surgical intervention in case of failure. Since one of the most important indications for PTCA is angina pectoris unresponsive to maximal drug therapy, the patients are usually taking a combination of oral long-acting nitrates, calcium antagonists and ß-blocking drugs.[46-49] The nitrates and calcium antagonists are continued for their anti-vasospastic activity but some workers discontinue the ß-blocker on the grounds that this drug can potentiate coronary vasospasm during PTCA. At Tygerberg Hospital ß-blockers are continued in cases of unstable angina pectoris, since these patients are likely to develop acute myocardial infarction on withdrawal, especially if this is rapid. There is much variation in drug protocol at various institutions but most agree that some form of antiplatelet therapy is necessary on account of the exposure of a 'raw area' after PTCA. Therefore, a combination of dipyridamole (Persantin) 100 - 200 mg 3 times daily and aspirin 75 - 100 mg daily is administered 1 - 3 days prior to PTCA. In Grüntzig's original description of the procedure aspirin was given in a dose of 1 g daily for 3 days starting 1 day before PTCA. Most workers appear to administer aspirin in these high doses despite the fact that it has been demonstrated that this dose decreases prostacyclin (PGI_2) synthesis (anti-vasospastic) and increases the activity of thromboxane A_2 (TXA_2) (pro-vasospastic). Because of these considerations we at Tygerberg Hospital have opted to give a small dose of aspirin in the form of 'Junior Aspirin' 75 mg (one-quarter the normal 300 mg tablet) daily, starting 2 days before PTCA, in addition to dipyridamole 100 mg 3 times daily. Some workers even begin heparin infusion a few days prior to PTCA. When the patient is in the cardiac catheterization laboratory a bolus of 10 000 units heparin sodium is administered via an infusion line in an arm vein and further boluses of 5 000 units every 35 minutes during the procedure. Low-molecular-weight dextran 40 (Rheomacrodex) is then infused at a rate of 250 ml in the first hour and a further 250 ml over the succeeding 4 hours.

Use of a prophylactic temporary pacemaker

A temporary bipolar pacemaker electrode is inserted percutaneously in the contralateral femoral vein and positioned