Chapter 6
Catheters and Wires

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6.1 Diagnostic Catheters

Diagnostic catheters are thin-walled tubes introduced into patient's vessels and the heart via the valved introducer sheaths. Structure of the catheter, its geometry, and other characteristics depend on the purpose it serves. There are many designs and technical solutions created by numerous manufacturers of catheterization equipment. Catheters are named according to their shapes, people who designed them, or the vessels they are supposed to enter. The basic principle of catheter selection, however, is that they must serve the purpose they are suitable for. Thus, in a pediatric cardiac catheterization laboratory, one often uses catheters designed for procedures other than those being performed. Nevertheless, there are some basic catheter categories that the operator has to be familiar with.

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6.1.1 Anatomy of the Catheter

Although diagnostic catheters usually look like simple plastic tubes, their construction is quite complex. Materials used should be safe for the patient, assure maneuverability, respond to the torque applied, be kink resistant, be resistant to the pressures generated during contrast injection, and assure good visibility on fluoroscopy.

Several properties are crucial when selecting a catheter. The outer diameter is traditionally given in French (F), representing outer circumference in millimeters (corresponding to about 0.3 mm of the outer diameter), inner lumen diameter in decimal fraction of inch (e.g., 0.035″), length in centimeters, maximal pressure in pounds per square inch (psi), and maximal flow in milliliters per second (ml/s).

There are some discrepancies in describing proximal and distal direction of the catheter. For the purpose of this chapter, the tip of the catheter will be called its distal end and the Luer-lock adapter its proximal end.

Catheter manipulation requires application of torque to its part outside the patient. This torque has to be transmitted to the tip. Besides, as mentioned before, the catheter has to be kink resistant and provide some support while passing through the vessels and/or chambers. This is why shafts of the catheters are usually composed of a plastic material (nylon, polyethylene, polyurethane, PTFE) braided with thin metal meshwork. Depending on the manufacturer, the catheter size and the distal ends of catheters can be made of braided or unbraided material. The tip itself usually lacks reinforcement to assure its softness and minimize the risk of vascular wall injury. The distal tip of the catheter may have an additional radiopaque marker to improve its visualization. Some of the catheters have a single end hole for injection of the contrast medium, for pressure measurements, and for advancing guidewire, while other catheters such as angiographic catheters have multiple side holes for even contrast distribution. It is recommended to avoid any pressure injections of contrast through a catheter with end hole only. Balloon-tipped catheters have a CO_2 inflatable balloon at their tips. This balloon is supposed to allow free floating with the blood stream and prevent tangling between the chordae tendineae in the cardiac chambers. Other catheters have hydrophilic coating that makes them slippery and facilitates their gliding through tortuous vessels. Sizing catheters have additional radiopaque markers embedded in their shafts at known distances, for precise calibration and measurements.

6.1.2 Types of the Catheters

6.1.2.1 Angiographic Catheters

The main purpose of the angiographic catheters is the appropriate visualization of anatomy by means of the injection of contrast medium into blood vessels or cardiac chambers. Multiple side holes at the end of the catheter help to distribute the contrast evenly and deliver it efficiently during ventriculography or angiography. End hole allows for over-the-wire insertion of the catheter. The angiographic catheters can withstand high pressure and flow of the contrast medium, without recoil of the catheter during the injection.

Pigtail catheters have their tip shaped in a shape suggested by their name (Figs. 6.1a and 6.2). They are thin walled especially at their distal ends, and this makes them soft but susceptible to kinking. Thus, pigtail catheters have to be advanced and withdrawn with the guidewire inside them. While passing through the arterial valves retrogradely, the loop of the guidewire should precede the tip of the catheter to prevent kinking in the valvar sinuses. Side holes are placed proximal to the curved tip. This should be kept in mind when positioning the catheter for contrast infusion or pressure measurement.

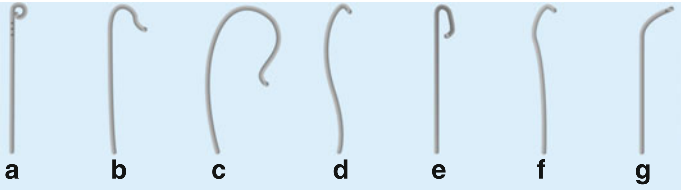

Fig. 6.1 Shapes of selected torque-controlled catheters (see text). (**a**) Pigtail catheter, (**b**) Amplatz left coronary catheter, (**c**) Amplatz right coronary catheter, (**d**) internal mammary catheter, (**e**) Judkins left coronary catheter catheter, (**f**) judkins right coronary catheter, (**g**) multipurpose catheter

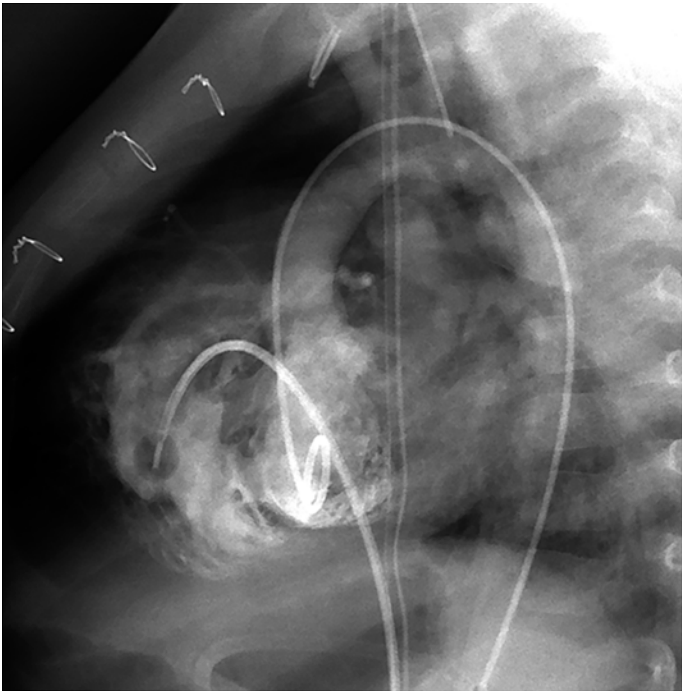

Fig. 6.2 Left ventriculography (retrograde approach) with pigtail catheter (Cordis, Miami Lakes, FL) – lateral projection. Multiple ventricular septal defects in a 2-year-old patient after pulmonary artery banding and surgical repair of aortic arch hypoplasia and coarctation

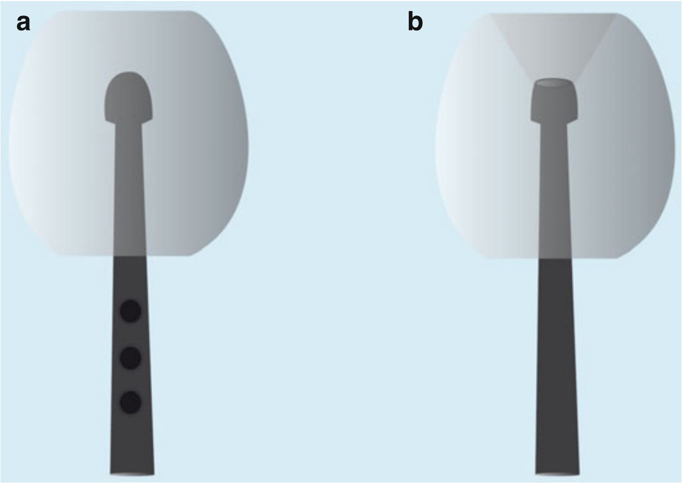

Fig. 6.3 Tips of floating catheters. (**a**) Berman angiography balloon catheter. (**b**) Pulmonary wedge balloon catheter

There are angiographic catheters of various curves available in the market. Special shapes have been designed for a variety of purposes, e.g., pulmonary angiography. Despite their different shapes and other features, the main principles remain the same. Therefore, they are not described in this chapter.

Berman angiographic catheter is a balloon-tipped catheter without the end hole (Fig. 6.3a). Thus, it cannot be advanced over a guidewire. Since it has a straight tip, the curved wire can be placed inside the catheter to shape it and support it when entering the desired location. The CO_2 inflatable balloon helps to cross the valves with the blood flow. Usually Berman catheter is used to access the right ventricle and the pulmonary arteries (Fig. 6.4). However, in the presence of interatrial or interventricular communications, it can be used to catheterize the left heart structures as well (Fig. 6.5). Antegrade approach to the

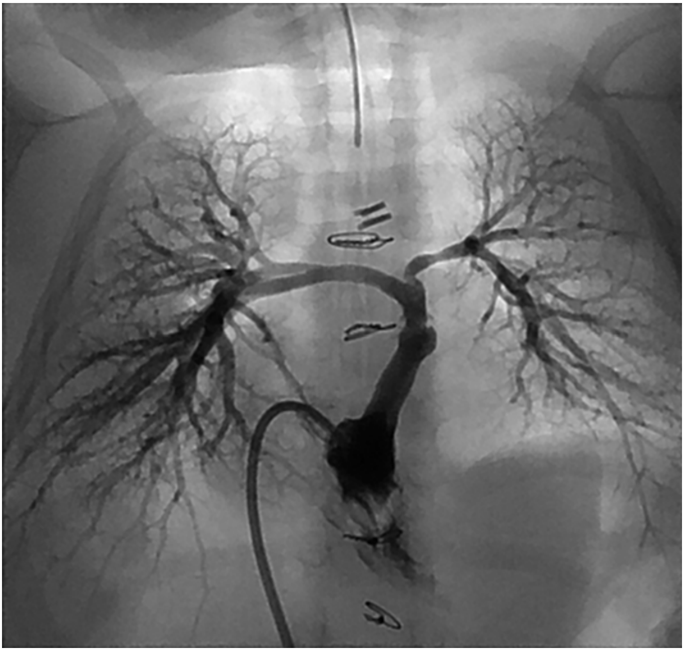

Fig. 6.4 Right ventriculography (antegrade approach) with Berman angiography balloon catheter (Arrow International Inc., Reading, PA) – cranially tilted frontal projection. Patient with hypoplastic right heart syndrome (weight 4 kg) after central shunt due to pulmonary artery hypoplasia

aorta is feasible also in patients with transposition of the great arteries, double outlet right ventricle, or functionally univentricular hearts or in the presence of large ventricular septal defects. Moreover, the balloon catheter can be used to occlude the distal parts of the vessels and perform occlusion arteriography. Antegrade balloon occlusion aortography with 35° caudal angulation is used to visualize coronary arteries in cases of transposition of the great arteries (Fig. 6.6). Balloon occlusion

Fig. 6.5 Aortography (antegrade approach) with Berman angiography balloon catheter (Arrow International Inc., Reading, PA) – cranially tilted frontal projection. The patient presented in Fig. 6.4

descending aortography helps to force blood flow through aortopulmonary collateral arteries in the tetralogy of Fallot and other congenital cardiac malformations with pulmonary stenosis or atresia (Fig. 6.7). In fenestrated Fontan patients, one can occlude the fenestration with the balloon tip in order to evaluate changes of blood pressure in the Fontan circulation. All these and many more applications make the Berman angiographic catheter an especially valuable item in the catheterization laboratory inventory.

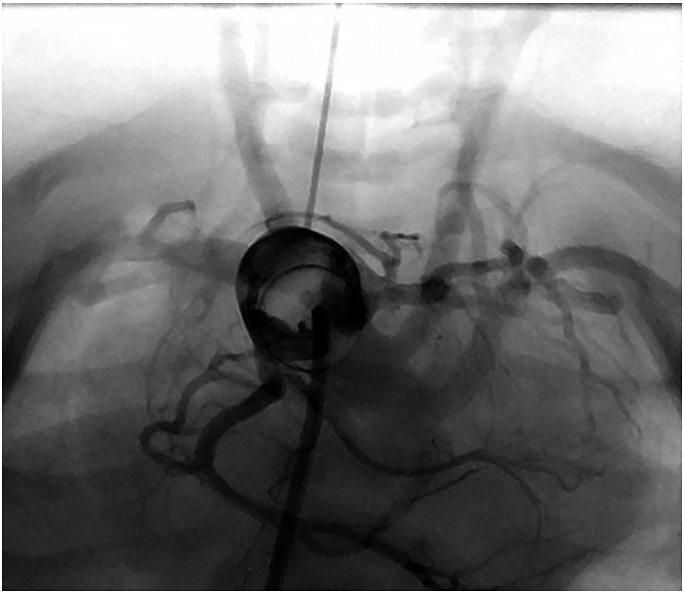

Fig. 6.6 Balloon occlusion ascending aortography (antegrade approach) with Berman angiography balloon catheter (Arrow International Inc., Reading, PA) – caudally tilted frontal projection. Anatomy of the coronary arteries (origin of the left circumflex artery from the right coronary artery) in a 2-day-old patient with transposition of the great arteries

6.1.2.2 Pulmonary Balloon Wedge Catheters

The pulmonary balloon wedge catheter (Swan-Ganz) is a single end-hole, balloon-tipped catheter, originally invented to measure right heart pressures. Its balloon tip makes it float to the distal pulmonary arteries (Fig. 6.3b). When it reaches the desired position, the inflated balloon occludes the antegrade flow in the vessel. Thus, the pressure in the pulmonary veins and the left atrium can be measured. When placed in the pulmonary

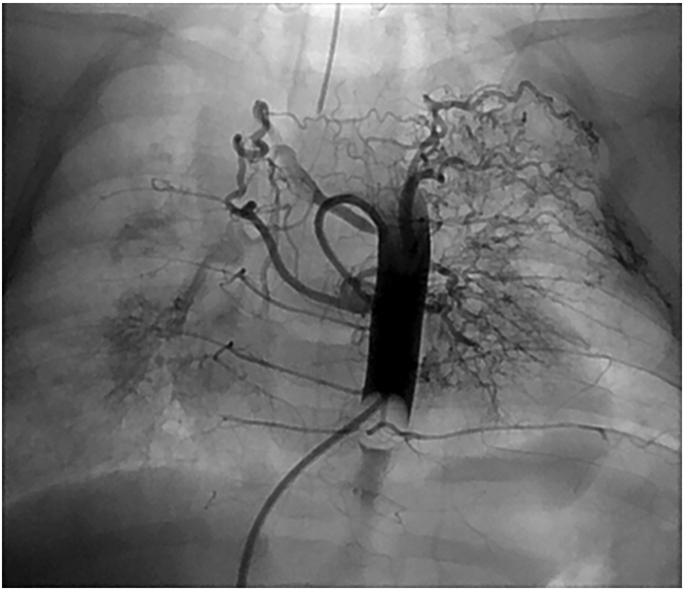

Fig. 6.7 Balloon occlusion descending aortography (antegrade approach) with Berman angiography catheter (Arrow International Inc., Reading, PA) – posterior-anterior projection. Aortopulmonary collaterals in a 6-month-old patient with double inlet left ventricle after pulmonary artery banding

vein, one can measure the pressure in the pulmonary arterial bed, based on exactly same principle as the antegrade pulmonary wedge measurement. However, in the hands of interventional cardiologist, the pulmonary balloon wedge catheter becomes more widely used for advancing the guidewire for interventional procedures, selective pulmonary arteriography, simulation of vessel occlusion, and many others. With the balloon inflated at its tip, it should cross the tricuspid valve safely and minimize the risk of its injury during the following interventions: balloon valvuloplasty, pulmonary arteries angioplasty, or stent placement. In case of extreme pulmonary artery hypoplasia, injection of the contrast medium through the catheter wedged in the peripheral pulmonary vein with consecutive flushing with saline results in retrograde visualization of the pulmonary arterial vessels. Antegrade placement of the Swan-Ganz catheter in the Blalock-Taussig shunt is used, after inflation of the balloon, to simulate the shunt occlusion and monitor pressure changes in the pulmonary arteries. Undoubtedly, the pulmonary wedge catheter should always be available for use in the catheterization laboratory shelf.

6.1.2.3 Curved Catheters

A large variety of curved catheters are designed for selective catheterization of blood vessels. As mentioned before, their names often suggest their particular application. However, the interventionist searching for "right ventricular outflow tract catheter" or "right Blalock-Taussig catheter" would be unsuccessful in finding these. The operator should base selection of the most useful equipment on personal preferences, experience of other specialists, knowledge of catheter properties, and the patient's anatomy. Most of the curved catheters have a single end hole. They can be used for selective angiography, pressure measurement, and guidewire placement.

Selected curved catheters are presented in Fig. 6.1. Some of these, described below, deserve some more attention.

- *Coronary catheters* are designed to easily intubate the normal coronary arteries. Judkins and Amplatz catheters are the most popular (Figs. 6.1b–e, 6.8, 6.9, 6.10, and 6.11). Among them, Judkins right coronary catheter (JR) is one of the most widely used in the cardiac catheterization laboratory. The distal part of the catheter is gently rotated to find support in the ascending aorta and the tip bends at almost a right angle to reach the

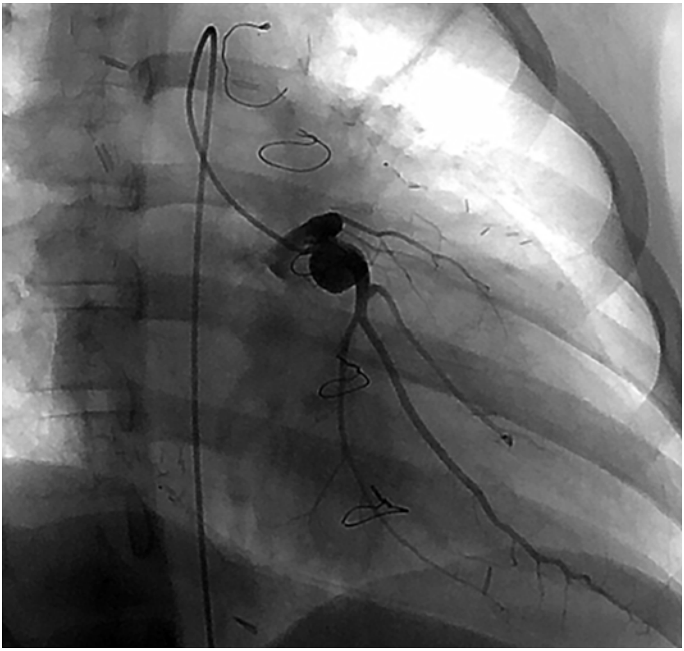

Fig. 6.8 Left coronarography (right anterior oblique projection) with Judkins left coronary catheter (Cordis, Miami Lakes, FL). Details of left coronary artery anatomy (aneurysms, interruption, stenosis) in a 10-year-old patient with Kawasaki disease after bilateral internal mammary arteries/coronary arteries bypass.

orifice of the right coronary artery. In pediatric catheterization laboratory, this shape has proved to be useful in the selective catheterization of Blalock-Taussig shunts and collateral vessels (Fig. 6.10). Furthermore, it appears to be the best catheter to enter the right ventricular outflow tract, in cases of extreme pulmonary valve stenosis and pulmonary atresia (Fig. 6.11). In crossing the restrictive interatrial communication in the hypoplastic left heart syndrome, it is worth

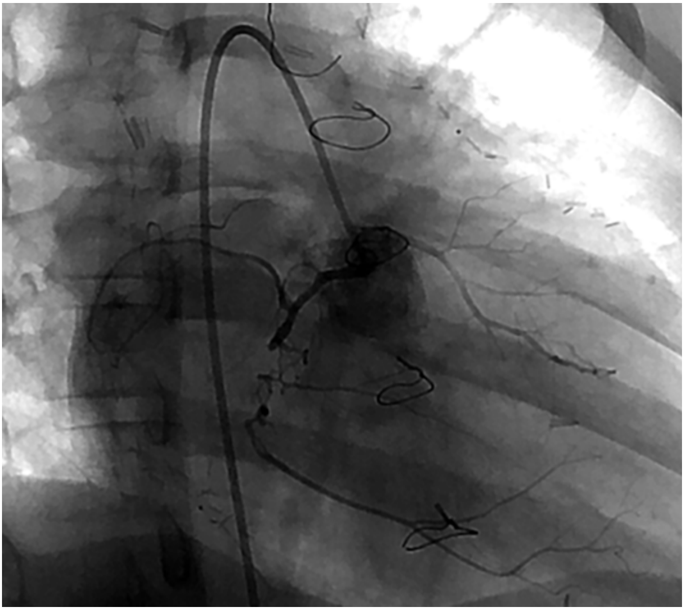

Fig. 6.9 Right coronarography (right anterior oblique projection) with Judkins right coronary catheter (Cordis, Miami Lakes, FL). Details of right coronary artery anatomy (interruption, stenosis) in the patient presented in Fig. 6.8

considering the use of JR catheter inserted over the guidewire to the superior vena cava and gently withdrawing it with the tip directed toward the interatrial septum. Prior to aortic valvuloplasty for neonatal critical aortic stenosis, the JR catheter is the best one for searching the orifice between the stenotic valvar leaflets (Fig. 6.12). JR catheter is also very useful in crossing the interventricular septal defects which is the important step in their interventional closure.

- *Internal mammary catheters* with their C-shaped tips can be used to enter vessels having origins at acute angles. Their

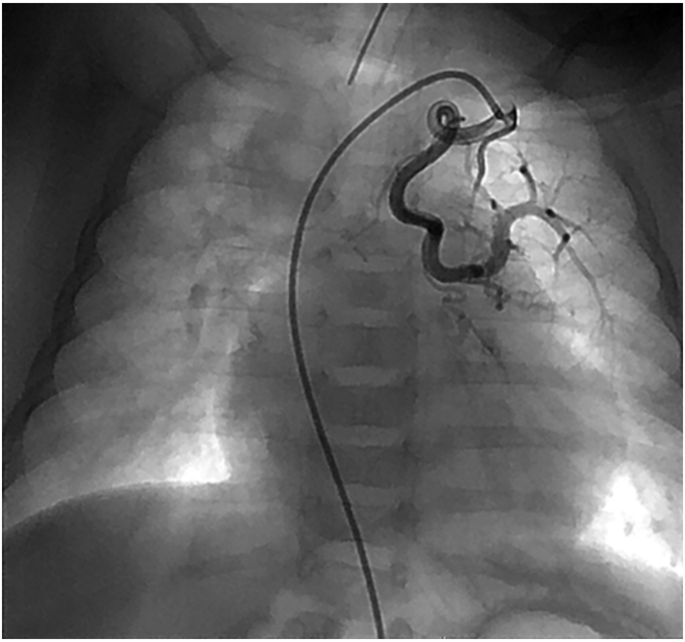

Fig. 6.10 Selective angiography of aortopulmonary collateral artery arising from the left subclavian artery with Judkins right coronary catheter (Cordis, Miami Lakes, FL) – posterior-anterior projection

applications include selective catheterization of Blalock-Taussig shunts and collateral vessels (Fig. 6.13).

- *Multipurpose catheters* have their distal ends curved at an obtuse angle (Fig. 6.1g). Usually there is at least one side hole near the tip. Such catheters, in accord with their name, can serve multiple purposes such as angiography, pressure measurement, and selective catheterization. They can be used to cross a tight coarctation, enter the branches of the aortic arch, reach the left atrium from the femoral vein and the right

Fig. 6.11 Right ventricle outflow tract angiography (lateral projection) with Judkins right coronary catheter (Cordis, Miami Lakes, FL). Right ventricle outflow tract anatomy and catheter position before radiofrequency valvotomy for pulmonary atresia in a 2-day-old patient

atrium, and place the guidewire in the pulmonary vein before atrial septal defect device closure.

6.1.2.4 Special Catheter Types

- The *Multi-Track angiographic catheter* (NuMED) has a short lumen for the guidewire at its tip. Thus, the tip can be introduced over the wire to a desired location, while the shaft

Fig. 6.12 Ascending aortography (retrograde approach) with Judkins right coronary catheter (Cordis, Miami Lakes, FL) – left anterior oblique projection. Catheter positioned in front of the opening of critically stenosed aortic valve in a 3-day-old patient allowing for easy insertion of the guidewire to the left ventricle and balloon valvuloplasty

remains free and multiple side holes remain open for use. This allows injection of contrast medium for angiography and measurement of pressures without losing the position of the guidewire.

- *Microcatheters* are superthin catheters that can be introduced through standard lumen (0.035–0.038″) single end-hole catheters for selective catheterization of small-size vessels. Once

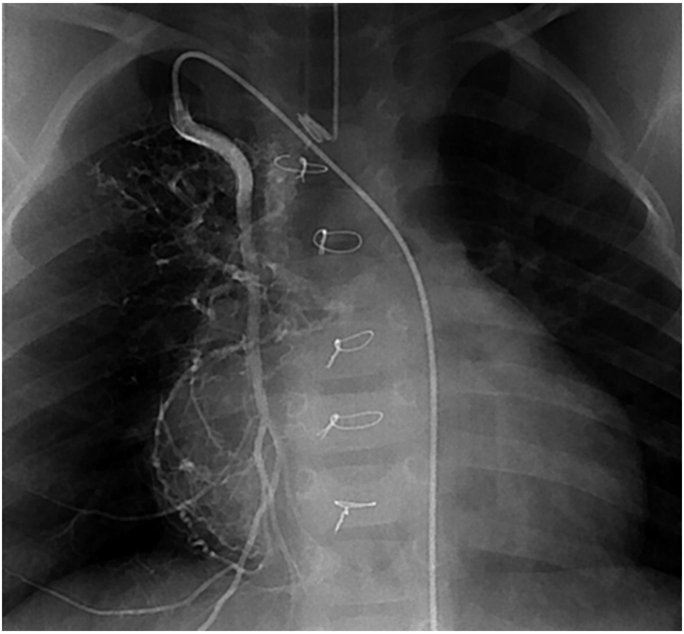

Fig. 6.13 Selective angiography of the right internal thoracic artery (posterior-anterior projection) with right internal mammary catheter (Cordis, Miami Lakes, FL). Small systemic-to-pulmonary collaterals in a 2-year-old patient with hypoplastic left heart syndrome after Norwood-Sano operation

the vessel is catheterized, one can deliver a microcoil through the guidewire lumen to occlude it. In pediatric and congenital cardiology practice, closure of small collateral vessels appears to be the major indication.

- *Guiding catheters* are single end-hole angled catheters in shapes similar to diagnostic catheters, but with much larger lumen, that permits advancement of interventional equipment. They are widely used in coronary interventions to introduce rapid exchange balloon catheters with a side hole for the guidewire. The walls of the guiding catheters usually possess a three-laminar structure with metal braiding in the middle layer. The size of the guiding catheter, given in French, reflects its outer circumference (as opposed to the introducer sheaths sized by their lumen circumference). In congenital heart disease patients, application of guiding catheters is limited.

6.1.3 Selection of the Catheter and Catheter Manipulation

Every operator has own experience-based preferences. Nevertheless, some points need to be considered. First of all, the goal of the procedure has to be specified. For example, in the right heart, catheterization for idiopathic pulmonary hypertension angiography is not a standard component, and the pulmonary wedge catheter is an obvious choice. Should right ventriculography or pulmonary angiography be planned, the Berman floating angiography catheter and multipurpose catheter are reasonable choices. Also the size of the catheter should match the objectives, because it determines the maximum flow and contrast injection pressure. In case the diagnostic catheterization is followed by the intervention, one has to check if the inner lumen can accept the appropriate guidewire or the device. Length is another parameter worth considering. It can be really annoying when after long time of manipulation the catheter is too short to reach its destination.

With all kinds of catheters, it is important to remember the anatomic details, find support sites for the catheter tip and the shaft, and consider the use of a guidewire to position a catheter or to shape it. Wherever possible, bi-plane fluoroscopy should be used during the procedure. Manipulation principles are different for floating catheters and torque-controlled catheters. Some guidelines and tips and tricks are presented below.

6.2 Floating Catheters

Floating catheters (Berman, Swan-Ganz) are very soft, and their response to torque is limited. They should float freely in the direction of the blood flow. Nevertheless, especially in difficult anatomy or valvar insufficiency, it may be difficult to manipulate them. Additionally, floating catheters are packaged in a curved manner, and it may be impossible to straighten them completely. The problem can start just after crossing the introducer sheath. Without the balloon inflated, they can enter side branches. Inflation of the balloon makes the catheter float to the right atrium. Once the right atrium has been reached, it is possible to enter the superior vena cava. Sometimes it is possible to direct the tip posteriorly with a gentle torque and push the catheter up to the superior vena cava. In case of failure, insertion of a straight guidewire may solve the problem. Without a guidewire inside and without the balloon inflated, the catheter is likely to enter the left atrium via an atrial septal defect or patent foramen ovale, if present. To enter the left pulmonary veins, the catheter should be directed posteriorly. Otherwise it will enter the left atrial appendage. Inflation of the balloon of catheter placed in the left atrium, close to the interatrial septum, followed by a clockwise torque may help to cross the mitral valve and enter the left ventricle. If this maneuver does not work, one can use the stiff end of the guidewire bent in a U-shape to angle the distal end of the catheter. Guidewire will also help to transmit the torque. In the left ventricle, the catheter will float toward the apex. Again, a curved stiff end of the guidewire may help to bend the catheter (with the balloon inflated) toward the interventricular septum and push it up into the aorta. To avoid the tension onto the ventricular wall, the guidewire should be partly withdrawn from the catheter, to permit free floatation of the balloon.

In most of cases, the catheter floats from the right atrium to the right ventricle. If this does not happen, an angled guidewire tip may be helpful to curve the catheter. Another solution is to find support for the catheter tip in the atrial wall, push it further to the atrium to make it bend, and then pull it back. The catheter should recoil and jump into the ventricle. The third method is to create a loop in the right atrium by pushing the catheter with some clockwise torque. Once the loop has been created, the catheter may enter the right ventricle and float to the outflow tract. The atrial loop can also be helpful to reach the right ventricular outflow tract, when the catheter keeps floating toward the ventricular apex. If it is stuck at the apex, a coiled guidewire can help to free it. Shaping the catheter with a guidewire is also useful to manipulate into the branch pulmonary arteries.

There are some issues to be kept in mind:

1. The balloon is able to accommodate more CO_2 than just one syringe; the more the balloon is inflated, the easier the floating is, but caution is needed as the balloon can rupture with too much CO_2.
2. The catheter can be straightened or bent using the guidewire; the guidewire helps to transmit the torque.
3. Creating a loop can help to manipulate the catheter; it is better to straighten the catheter as soon as its final destination has been reached.
4. Especially in blood vessels, the balloon can obstruct them and alter the blood pressure; it should be deflated during measurements of pressure.
5. In selected applications, obstruction of the vessel with the balloon tip can help to make a selective contrast injection or perform an occlusion test; always remember where the hole(s) is (are).
6. When performing balloon occlusion angiography, the vessel occlusion time should be kept to a minimum; after inflation of the balloon, the catheter will float downstream – pull it back to the desired position and deflate the balloon as soon as the angiography has been performed.

6.2.1 Torque-Controlled Catheters

Most of the catheters are torque controlled. The torque is applied by the operator at the proximal end of the catheter. Most of catheter tips lack braiding. That makes them soft and susceptible to kinking. While crossing the blood vessels, angled tips may tend to enter side branches/tributaries. If this problem occurs, they should be introduced over a guidewire. This is mandatory for pigtail catheters. Applications of selected catheters have been discussed already.

The importance of selection of an appropriate catheter shape is undisputed. Sometimes the shape has to be modified to reach a desired location. One can use a guidewire to make the angled catheter straight. On the other hand, the stiff end of a guidewire can be used to apply additional curvature. Entering the right ventricular outflow tract with the Judkins right coronary catheter is a good example. The catheter introduced to the right atrium will tend to move to the superior atrial wall, the right atrial appendage, the superior vena cava, or the left atrium through the atrial septal defect. One can, however, bend the catheter with an angled guidewire and then withdraw it to allow entry into the right ventricle. Torque applied to the catheter will direct the tip to the outflow tract. Should a new shape be permanent, one can reshape it by placing the catheter in hot water or in steam with a stiff, pre-shaped guidewire inside. When the new shape is achieved, the catheter has to be cooled in saline.

Sometimes it is relatively easy to enter an origin of the blood vessel, but the guidewire makes the catheter recoil instead of entering the vessel. This may happen in major aortopulmonary collateral arteries and Blalock-Taussig shunts. If the catheter shaft is pushed excessively, an angle between the shaft and the tip inside the vessel may become too acute. Under such conditions, the guidewire tip is unable to straighten the catheter tip, it pushes the catheter further, and the tip recoils. Hence, it is better to straighten the angle by pulling the catheter down.

6.3 Guidewires

There are plenty of guidewire types and designs used in cardiac catheterization laboratory, produced by numerous manufacturers. Spring guidewires are composed of inner core made of stainless steel or nitinol, accompanied by a fine, steel safety wire and outer fine steel winding. Most of spring wires are coated with polytetrafluoroethylene and sometimes heparin to prevent clotting. In the distal part of the guidewire, the core narrows or there is just a safety wire and outer winding. It makes the tip soft and limits a risk of injury to the vascular or cardiac wall. The soft tip can adapt to a vessel shape and cross stenotic areas and tortuosities. Wires with “floppy” tips can be especially useful in such setting. Tips of guidewires are straight or curved. J-tips are the most frequently found. The stiffer the wire is, the more support it provides to diagnostic or therapeutic catheters. Guidewires with a core wire extending from the proximal to distal end can transmit the torque 1:1 or near to it, what makes them more maneuverable. Tips commonly have platinum, gold, or tungsten elements to make them more radiopaque. Also guidewire shafts can be coated with, e.g., polyethylene/tungsten material to enhance their visibility on fluoroscopy.

- Guidewires with hydrophilic coating are slippery when wet. They glide through tortuous vessels easily. It can be difficult to manipulate them, so a special plastic torque device is very useful. Hydrophilic wires have to be wet all the time, because they become sticky when dried.
- Steerable guidewires have an additional filament attached to a proximal handle. An operator can change shape of their tip by moving the handle. Thanks to the nitinol core, the tip returns to its initial shape. Such guidewires are used to navigate through tortuous vessels or cross the stents without passing between the struts.

- Pressure wires are equipped with a pressure transducer at their tip. Initially, pressure wires were designed to measure pressure gradients across stenotic coronary arteries to assess fractional flow reserve. Gradually, other applications were developed, e.g., measurement of pressure gradients through stenotic valves or vessels such as banded pulmonary arteries in patients after hybrid procedures for hypoplastic left heart syndrome.

Size of a guidewire is given in fraction of inch. The length is measured in centimeters. Especially long (260–300 cm) exchange wires are used to exchange long catheters (Fig. 6.14). Some guidewires can be additionally extended using extension wires.

Guidewires are used to guide diagnostic catheters, therapeutic catheters, guiding catheters, and introducer sheaths through the heart or the blood vessels. Selection of the guidewire has to match the purpose of its usage. One has to consider:

1. Diameter of the guidewire: the operator should know what size the catheter is able to accommodate. Generally, back-bleed ports with flush port should be used to prevent bleeding and formation of thrombi. It becomes especially important in huge catheter lumen/guidewire disproportion, since the bleeding can be significant. In case a flush port is not available, one has to remember to rinse the wire with heparinized saline frequently. If the intervention is needed, the size of the wire has to be chosen according to the lumen of interventional equipment, e.g., a balloon catheter.
2. Length of the guidewire: when it is too short, it will not leave the catheter tip or may be unable to reach a desired position. It can also be impossible to exchange catheter over the wire. As mentioned before, some guidewires can be extended if needed.
3. Hydrophilic coating: it helps to cross tortuous vessels and narrow stenoses. In spite of the softness of hydrophilic catheter tip, it can easily perforate the heart or vessel wall, especially while exiting the catheter. That is why rather standard guidewires and not hydrophilic nor thin coronary wires are

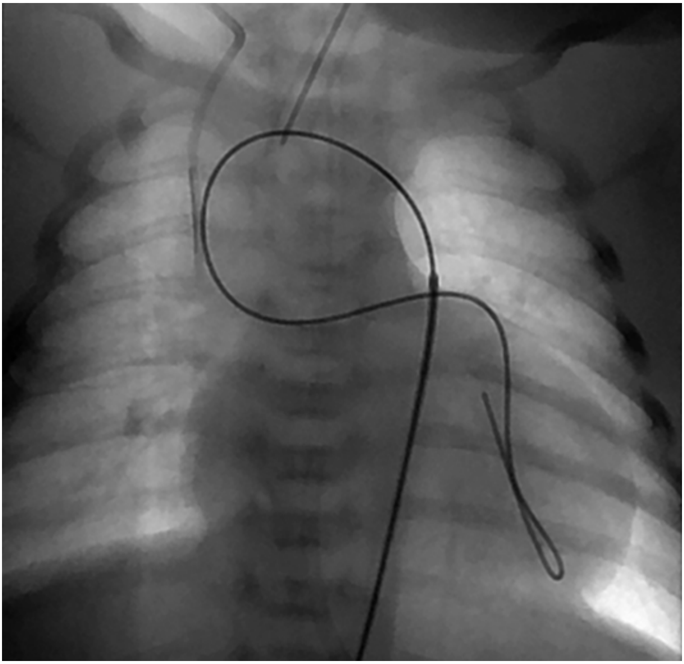

Fig. 6.14 Guidewire (Cook Inc., Bloomington, IL) position before stent placement to critical left pulmonary artery stenosis in a 3-week-old patient with complex congenital heart defect and duct-dependent pulmonary circulation after modified right Blalock-Taussig shunt. Guidewire introduced retrogradely from the aorta via the right Blalock-Taussig shunt, right and left pulmonary arteries to the distal branch of the left lower lobe pulmonary artery. Soft part of guidewire curled in the distal pulmonary artery branch for better support for the stent implantation

recommended to cross a critically stenotic aortic valve. The latter are more likely to perforate valvar leaflets.

4. Length of a soft tip: long, soft tips can enter the planned location but appear too extensive to support interventional equipment. On the other hand, guidewires with short tips are more traumatic.

5. Stiffness: it is safer and easier to advance catheters or sheaths using a stiff wire because of the better support. Softer wires can kink and lose their position or just make advancement of equipment impossible.
6. Shape of a tip: J-tipped guidewires are considered to advance more easily without entering side branches or tributaries. Nevertheless, the vessel diameter has to be large enough to accommodate the tip. Curved tips of some guidewires help to manipulate with the torque to reach a chosen location. Steel-core wire tips can be formed by an operator to get the best shape she/he needs.
7. Torque transmission: wires with a core continuous from proximal to distal end transmit the torque better than those lacking the core at their tips. The longer the floppy tip is, the more is the torque transmission limited.
8. Trackability and steerability: the shaft of the wire should be able to follow its tip through the tortuosities or narrowings in accord with operator's maneuvers.

As described in the section about catheter manipulation, stiff proximal end of a guidewire can be used to bend or shape catheter tips. One has to be cautious to not exit the catheter with a stiff end of the wire, as it can damage or perforate vascular structures or walls of cardiac chambers.

6.4 Introducer Sheaths

Introducer sheaths are used to assure safe vascular access, allow the insertion of catheters and interventional equipment, and help to guide the devices through tortuosities of the cardiovascular system. The sheaths are usually equipped with a back-bleed valve to prevent an excessive blood loss and a side port for flushing, pressure measurements, and, occasionally, contrast infusion.

The sheath is a thin-walled plastic tube composed of the material rigid enough to prevent kinking in the blood vessels. Their size reflects the inner diameter of the tube, i.e., the diameter of the dilator used to allow the smooth passage through the vascular wall. Thus, 4 French introducer sheath can accommodate 4 French catheter. The outer dimension of the sheath is wider and depends on the thickness of the material the tube is made of. Dilators have a long, tapered tip sticking out of the sheath. The dilator and sheath locked together are introduced to a blood vessel over the wire. Size of the dilator inner lumen should be known to the operator, especially in case there is a need to exchange the sheath and use the one of the other size.

Short introducer sheaths are used to maintain the vascular access and manipulate with the equipment. Their length should match the anatomy of the vessels – the sheath should not end opposite to a vascular wall, since it can produce complications such as vascular wall injury and bleeding. Long sheaths are used to straighten blood vessels and create a smooth tunnel for diagnostic and, especially, interventional equipment, such as stents, occluders, vascular plugs, biopsy forceps, or transseptal needles. Most of them can be recurved using hot steam or air to meet the needs of particular procedures. Mullins sheath is a long, curved sheath with multiple diagnostic and interventional applications. High flexibility and ability to pass through especially tortuous vessel without kinking or collapsing are the features of long Super Arrow-Flex sheath. Details of long sheaths usage are presented in chapters devoted to specific procedures.

Back-bleed valves and side ports can be an integral part of the introducer sheath or be separate devices attached to the Luer lock at the end of the sheath. Usually, the back-bleed valve incorporated into the sheath is a latex diaphragm with a hole that permits insertion of the equipment. Resistance of such valve can significantly influence the effectiveness of manipulation and transmission of the torque applied to catheters and wires. In case of some introducer sheaths, the structure and rigidity of their valves make the effective manipulations impossible. The valves with a screw-tightened hub (Tuohy type) can be regulated according to the needs of the operator. Detachable back-bleed valves with side ports can also be removed once the device is in the sheath and obturates its lumen, so that the control over the equipment is easier and more effective.

Suggested Reading

1. Grifka RG (2008) Cardiac catheterization and angiography. In: Allen HD, Driscoll DJ, Shaddy TR, Feltes TF (eds) Moss and Adams' heart disease in infants, children, and adolescents: including the fetus and young adults, 7th edn. Lippincott Williams & Wilkins, Philadelphia, pp 209–238
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3. Mullins C (2006) Balloon dilation procedures – general. In: Mullins C (ed) Cardiac catheterization in congenital heart disease: pediatric and adult. Blackwell Futura, Massachusetts, pp 163–223