Catheterizing the Right Heart from the Femoral Vein

A right (as well as a left) heart catheterization is needed to obtain a full profile of the hemodynamic state. Only the right heart catheterization can provide data regarding mean left heart filling pressure (the pulmonary capillary wedge, rather than just the post–A wave left ventricular end diastolic pressure), detect pulmonary arterial hypertension, measure the cardiac output, and detect left-to-right intracardiac shunts. Leaving the right heart catheter in the pulmonary artery during a complex interventional procedure also gives an ongoing measure of changes in the hemodynamic state as fluid and contrast loading take place, various medications (nitrates, diuretics, and so on) are given, and as episodes of ischemia develop and are treated.

For these reasons, it was once common to perform a right heart catheterization in *every* patient who came to the cardiac catheterization laboratory. In contrast, the 1990 SCA&I survey showed that the practice was to perform right heart catheterization in only 28% of procedures (5). The use of right heart catheterization has fallen further after several standard-setting and regulatory agencies ruled that a left heart catheterization alone is adequate for most patients undergoing evaluation for coronary artery disease. The time (<5 minutes), added expense (<$100), and added risk (<1/10,000) of right heart catheterization are small, but so is the added information. So we now skip the right heart catheterization in patients with a primary diagnosis of coronary artery disease, unless they have symptoms of congestive heart failure, noninvasive evidence of depressed left ventricular function or associated valvular disease, or recent myocardial infarction. In such patients, however, we still believe that the quantitation of overall hemodynamic function provided by right heart catheterization justifies performance of this low-risk adjunctive part of the overall catheterization evaluation.

If right heart catheterization *is* to be performed, the desired right heart catheter (Fig. 4.5) is flushed, attached to the venous manifold, introduced into the sheath, and advanced up the inferior vena cava. Although conventional woven Dacron (Goodale-Lubin or Cournand) catheters provide excellent torque control, their inherent stiffness makes them poorly suited for routine use in a training laboratory. It is considerably safer to use 7F balloon flotation catheters to exploit their ease of passage, low risk of injury to the right-sided heart chambers, and (with a suitably equipped catheter) their ability to perform thermodilution measurements of cardiac output. Unfortunately, such soft catheters with smaller internal diameters tend to have poor frequency response (see Chap. 7), may not adequately transmit the torque required for easy catheterization of the right-sided heart from the femoral approach, and accept only 0.021-inch guidewires. To bridge this gap,

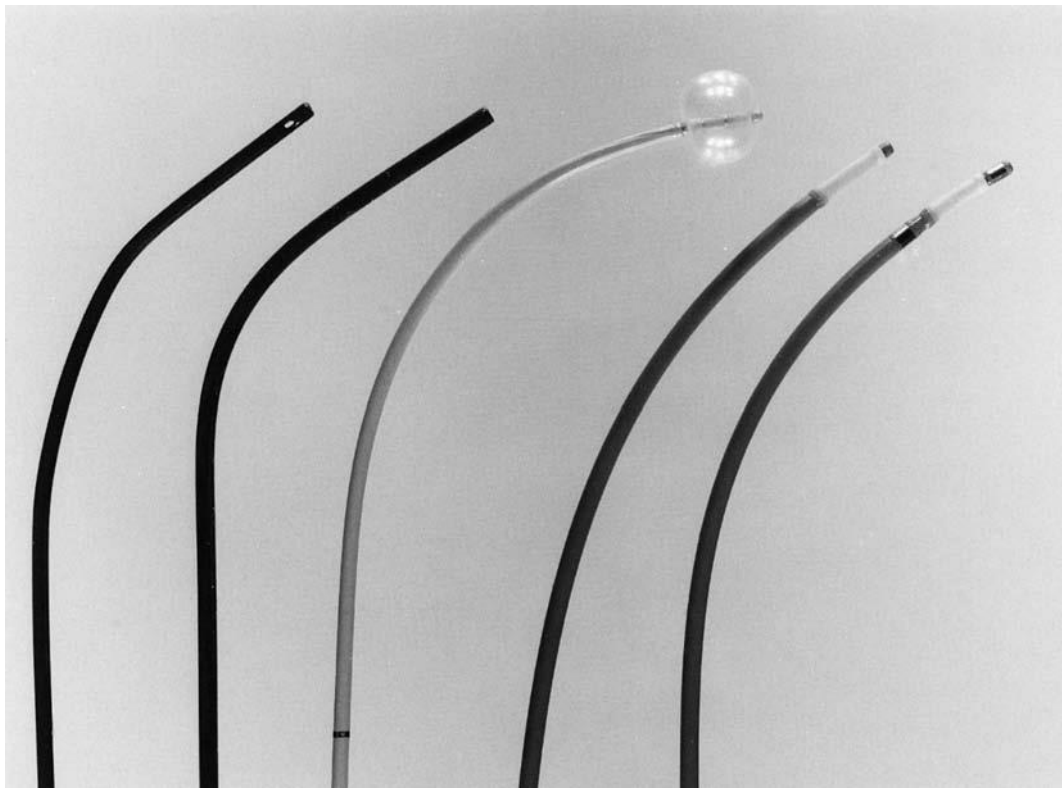

Figure 4.5 Right-sided heart catheters used from the femoral approach. **Left.** Woven Dacron Goodale-Lubin, Cournand catheters. **Center.** Swan-Ganz catheter. **Right.** Newer balloon catheters, including the PWP pressure measurement catheter and the Baim-Turi catheter with bipolar pacing electrodes (USCI).

stiffer, balloon-tipped catheters (PWP monitoring catheter, Medtronic) have been developed that combine the safety of the Swan-Ganz catheter with the catheter control and frequency response previously found only in the woven Dacron catheters. The larger lumen diameter also allows the passage of conventional 0.035- and 0.038-inch diameter guidewires when necessary.

Deviation of the catheter tip from its paraspinous position during advancement from the leg suggests entry into a renal or hepatic vein, which can be corrected by slight withdrawal and rotation of the catheter. Once the catheter is above the diaphragm and within the right atrium, it is rotated counterclockwise to face the lateral wall of the right atrium (Fig. 4.6). Additional counterclockwise rotation and gentle advancement allow passage of the catheter tip into the superior vena cava, which is contiguous with the posterolateral wall of the right atrium. In contrast, anterior orientation of the catheter tip at this point may result in its entrapment in the right atrial appendage and inability to reach the superior vena cava. If passage to the superior vena cava is difficult, the tip of the catheter can be withdrawn to the inferior vena cava, where a 0.035-inch J guidewire can be introduced to traverse the straight-line path from the inferior to the superior vena cava along the back wall of the right atrium. Once in position, a baseline superior vena caval blood sample is obtained for measurement of oxygen saturation and comparison with the subsequently measured pulmonary arterial blood O_2 saturation to screen for unsuspected left-to-right shunts. The catheter is then flushed with heparinized saline solution and withdrawn to the right atrium for pressure measurement.

To advance a catheter from the femoral vein to the pulmonary artery, the tip of the catheter is positioned in the lower portion of the right atrium, directed toward its lateral border. If a balloon flotation catheter is being used, the balloon is inflated at this point. Clockwise rotation is applied, which causes the catheter tip to sweep the anterior and anteromedial wall of the right atrium, along which the tricuspid valve is located (Fig. 4.6). As the catheter tip passes over the tricuspid orifice, slight advancement causes it to enter the right ventricle, where pressure is again recorded. If the right atrium is enlarged, greater curvature of the catheter may be necessary, i.e., a large J loop. Such a loop may be formed by bending the tip of the catheter against the lateral right atrial wall or by engaging in the ostium of the hepatic vein (just below the diaphragm). This larger loop can then be rotated clockwise in the atrium as described above, causing the tip of the catheter to enter the right ventricle. Right ventricular pressure is then recorded.

Simple advancement of the catheter in the right ventricle causes the tip to move toward the apex of that chamber

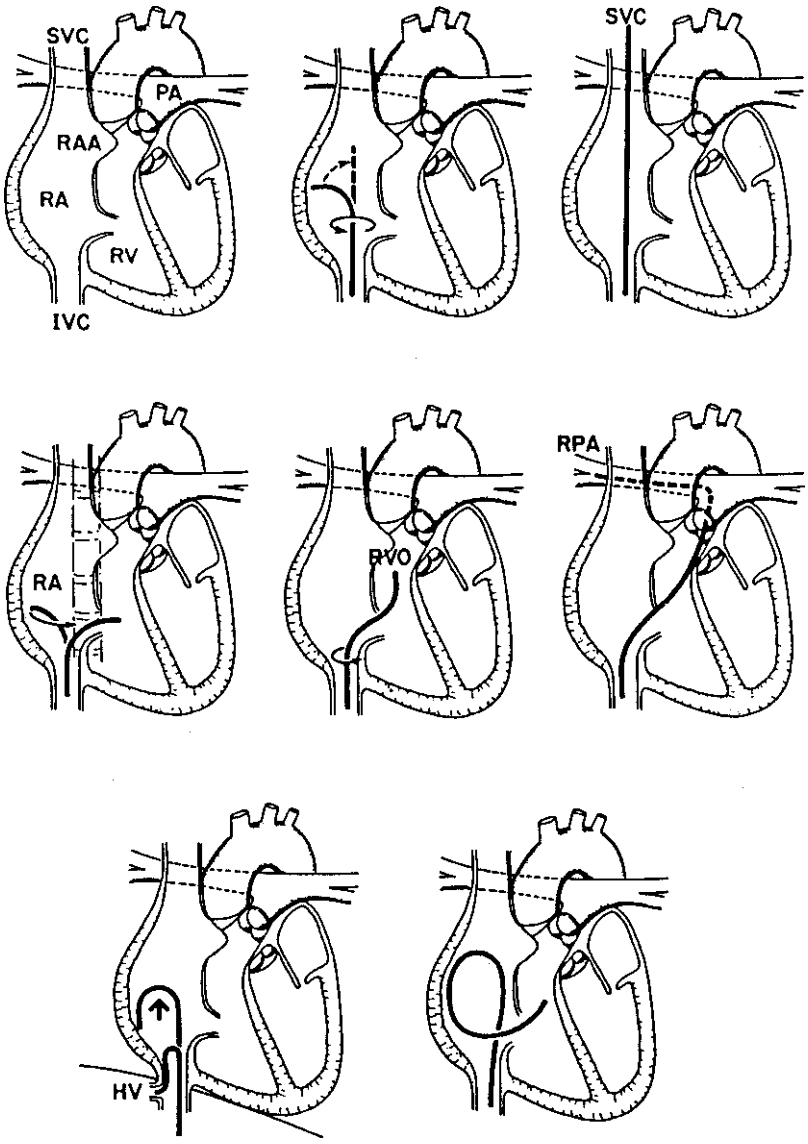

Figure 4.6 Right heart catheterization from the femoral vein, shown in cartoon form. **Top row.** The right heart catheter is initially placed in the right atrium (RA) aimed at the lateral atrial wall. Counterclockwise rotation aims the catheter posteriorly and allows advancement into the superior vena cava (SVC). Although not evident in the figure, clockwise catheter rotation into an anterior orientation would lead to advancement into the right atrial appendage (RAA), precluding SVC catheterization. **Center row.** The catheter is then withdrawn back into the right atrium and aimed laterally. Clockwise rotation causes the catheter tip to sweep anteromedially and cross the tricuspid valve. With the catheter tip in a horizontal orientation just beyond the spine, it is positioned below the right ventricular outflow tract (RVO). Additional clockwise rotation causes the catheter to point straight up, allowing for advancement into the main pulmonary artery and from there into the right pulmonary artery (RPA). **Bottom row.** Two maneuvers useful in catheterization of a dilated right heart. A larger loop with a downward-directed tip may be required to reach the tricuspid valve and can be formed by catching the catheter tip in the hepatic vein (HV) and advancing the catheter quickly into the right atrium. The reverse loop technique (bottom right) gives the catheter tip an upward direction, aimed toward the outflow tract.

and usually does not result in catheterization of the pulmonary artery. To achieve this latter end, the catheter must be withdrawn slightly so that its tip lies horizontally and just to the right (patient's left) of the spine. In this position, clockwise rotation causes the tip of the catheter to point upward (and slightly posteriorly) in the direction of the right ventricular outflow tract (Fig. 4.6). The catheter should be advanced only when it is in this orientation to minimize the risk of ventricular arrhythmias or injury to the right ventricle. Advancement may be facilitated if performed as the patient takes a deep breath.

If these maneuvers fail to achieve access to the pulmonary artery owing to enlargement of the right atrial and ventricular chambers, the catheter may be withdrawn to the right atrium and formed into a large reverse loop, which allows the tip of the catheter to cross the tricuspid valve in an upward orientation (similar to that when right heart catheterization is performed from above), which makes it more likely to enter the outflow tract (Fig. 4.6, bottom right). When manipulated appropriately, the catheter tip should cross the pulmonic valve and advance to a wedge position without difficulty. Having the patient take a deep breath and cough during advancement is often of assistance in achieving a wedge position. Alternatively, a small amount of air may be released from the balloon to decrease its size and facilitate wedging in a smaller, more distal branch of the pulmonary artery. Catheters advanced from the leg are more likely to seek the left pulmonary artery, whereas catheters advanced from above tend to seek the right pulmonary artery as they make a continuous counterclockwise curve through the right heart chambers. If needed, either pulmonary artery can be catheterized by appropriate manipulation or careful introduction of a curved J guidewire, but extending guidewires into the thin-walled pulmonary arteries should be avoided unless absolutely necessary.

Following measurement of the wedge pressure, the balloon (if a balloon-tip catheter is being used) is deflated

and the catheter is withdrawn into the more proximal left or right pulmonary artery. There, pulmonary arterial pressure is measured and another blood sample for measurement of oxygen saturation is obtained. If a more simultaneous "snapshot" of the hemodynamic state is desired, these entry pressures can be re-recorded during a right-sided heart pull-back. For practical reasons, we now tend to re- record only the wedge pressure (simultaneous with the left ventricular pressure) and pulmonary artery pressure, coin- cident with the measurement of the cardiac output. When baseline hemodynamics are abnormal, we commonly leave the right heart catheter in the proximal pulmonary artery for the duration of the case to allow continuous monitoring of the pulmonary artery diastolic pressure as an index of volume status and ischemic left ventricular dysfunction.

Attempts to perform right heart catheterization occasionally result in entry into other structures. If a woven Dacron catheter is advanced in the right atrium with a pos- teromedial orientation, it may cross a patent foramen ovale and enter the left atrium. This is sometimes hard to detect by catheter position alone because the catheter appearance in the left atrium or ventricle may be indistin- guishable (in the anteroposterior view) from its course during usual right heart catheterization. It can, however, be recognized by a change to a left atrial pressure waveform, position of the catheter tip across the spine and frequently out into the left lung field (i.e., into a pulmonary vein, Fig. 4.7A and B), and the ability to withdraw fully oxygenated blood from the catheter tip. Although more unusual, a woven Dacron catheter can also enter the ostium of the coronary sinus, located inferiorly and poste- riorly to the tricuspid orifice. There will be continued pres- ence of a right atrial waveform, but blood sampling will disclose far lower oxygen saturation (20 to 30%) than was present in the superior vena cava. In the right anterior oblique projection, the catheter will be seen to remain in the atrioventricular groove rather than passing rightward into the ventricle. Anatomic abnormalities can also be sus- pected when the catheter takes an unusual position or course during attempted right heart catheterization. Figure 4.7C, D, and E depict the appearance of the right-sided heart catheter course in three such congenital abnormali- ties (persistent left superior vena cava, patent ductus arte- riosus, and anomalous pulmonary venous return). *The most important points about these side trips off the beaten path to the right ventricle are that the operator should recognize that the tip of the catheter is not in the right ventricle (i.e., one should not attempt to get to the pulmonary artery) and should decide where the catheter is (by pressure monitoring, saturation analysis, or hand injection of a small amount of contrast agent) before withdrawing the catheter to the right atrium and proceed- ing with the right heart catheterization.*

In patients with elevated right heart pressures or prior placement of an inferior vena caval filter or umbrella, those undergoing specialized procedures (endomyocardial

biopsy, coronary sinus catheterization), or those in whom prolonged postprocedural monitoring with a balloon flotation catheter is desired, the *right internal jugular vein* offers an excellent alternative to the femoral vein. The tech- nique for jugular puncture is described in Chapter 20, and the method of advancing the right-sided heart catheter to the pulmonary artery is identical to that described for the brachial approach in Chapter 5. On occasion, percuta- neous right heart catheterization is performed from the subclavian or median basilic vein, using a similar tech- nique.