Radiolabeling Red Blood Cells Using A Hickman Catheter

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Patients with surgically inserted Hickman indwelling catheters present special problems for performance of multigated cardiovascular nuclear medicine studies. The routine procedure for performing such studies—labeling red blood cells in vivo with stannous pyrophosphate followed 20 min later by administration of Tc-99m sodium pertechnetate—does not provide clinically acceptable images when the Hickman catheter is used to administer the drugs. We describe an in vitro procedure to label red blood cells that are obtained via the Hickman catheter; this method results in improved in vivo cardiovascular nuclear medicine studies.

The in vivo method of labeling red blood cells (RBCs) with Tc-99m is commonly used for vascular compartment localization of radioactivity. It is primarily used in cardiovascular procedures for the evaluation of regional myocardial motion and calculation of ventricular ejection fraction.

Patients with leukemia, malabsorption syndrome, cystic fibrosis, ulcerative colitis, bone marrow transplants, and others who require frequent access to their circulation often have surgically inserted indwelling catheters to spare them the ordeal of repeated venipunctures. For such patients use of the Hickman indwelling right atrial catheter can eliminate the two venipunctures necessary for in vivo RBC radiolabeling.

Methods

The Hickman catheter is a large gauge (1.6 mm), polymeric, silicone rubber catheter (*1*). Using fluoroscopy and local anesthesia, the surgeon inserts the catheter into the cephalic vein and through the superior vena cava until the tip enters the right atrium. The catheter's distal end is anchored beneath the skin between the right nipple and sternum in a man or above or near the nipple line in a woman. The distal end of the catheter is threaded so the rubber injection cap can be easily attached and removed.

Blood Collection: To draw blood, the Hickman catheter is clamped with rubber-tipped clamps to prevent any perforation. The junction of the rubber injector cap and catheter is cleaned with povidone-iodine, allowed to dry, and cleaned with an alcohol wipe. The rubber injection cap is removed and a 3-way stopcock attached. Then the clamp is removed from the catheter, a 5-ml syringe is attached to one port of the stopcock, and 5 ml of blood is removed slowly. For the particular study we describe, this blood sample was discarded since it contained 2-ml (2000 units) of heparin, which would interfere with the Tc-99m labeling procedure. A 20-ml syringe containing 4 ml of acid-citrate dextrose anticoagulant is then attached to the second port of the stopcock and 20 ml of blood withdrawn for labeling. Next, a total of 2 ml (2000 units) of sodium heparin is administered through the stopcock to fill the catheter line with anticoagulant and the catheter clamped. After cleaning the stopcock-catheter junction, the stopcock is replaced with a sterile rubber injection cap and the catheter clamp removed.

Radiolabeling: A commercial kit (Mallinckrodt Nuclear, St. Louis, MO) containing 12-mg (2.1-mg Sn^{+2}) stannous pyrophosphate is reconstituted with 5.0 ml of preservative-free 0.9% NaCl. This vial is used for in vivo RBC labeling by the direct venipuncture method in patients who do not have indwelling catheters.

To prepare a dilution of stannous pyrophosphate for use in the in vitro labeling procedure, 0.1 ml of the reconstituted stannous pyrophosphate containing 0.24 mg of stannous pyrophosphate (0.042 mg Sn^{+2}) is added to a sterile, pyrogen-free vial containing 9.9 ml of preservative-free 0.9% NaCl. This vial contains stannous pyrophosphate in a concentration of 0.024 mg/ml (0.0042 mg/ml or 4.2 μg/ml Sn^{+2}). Working in a laminar flow hood, we added a total of 0.5 ml containing 0.012 mg stannous pyrophosphate (2.1 μg Sn^{+2}) to 20 ml of anticoagulated blood through the syringe tip.

A luer tip cap is placed on the syringe; this is then rotated 14 times/min for an incubation period of 10 min. The whole blood mixture is centrifuged in the syringe at 500 g for 10 min. The RBC fraction is carefully transferred to a lead-glass shielded 5-ml syringe containing 25 mCi of sodium pertechnetate in 0.5 ml of 0.9% NaCl. The shielded syringe is incubated on the rotator at 14 times/min for 10 min.

Administration of Labeled RBCs: The catheter is clamped with rubber-tipped clamps and the adapter-catheter junction cleaned as before. The rubber injection cap adapter is removed and a 3-way stopcock attached. After removing the clamp, a 5-ml blood/heparin mixture is removed from the catheter line and discarded. The second port of the stopcock is used to administer the Tc-99m RBCs followed by a 10-ml 0.9% NaCl rinse. Finally, 2 ml of sodium heparin (1000 units/ml) is administered through the stopcock to fill the catheter space with anticoagulant. The catheter is clamped and the stopcock replaced with a new sterile rubber injection cap adapter. The

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clamp is removed, the catheter secured by tape, and the patient positioned for imaging.

At completion of the gated blood pool scan, about 45 min after injection, the sterile manipulation of the catheter (as described previously) is used to obtain 0.3 ml of blood for determination of percentage of circulating activity associated with RBC fraction. Each patient's sample is transferred to a test tube and centrifuged at 500 g for 10 min. Equal aliquots of the RBC fraction and plasma fraction are counted in a gamma scintillation counter. The labeling efficiency is calculated according to the formula:

$$\text{\% circulating activity associated with RBC fraction} = \frac{\text{net RBC cpm} \times 100}{(\text{net RBC cpm}) + (\text{net plasma cpm})}.$$

Results and Discussion

Early success with RBC labeling and Tc-99m involved in vitro methods that required extensive manipulation during separation and washing procedures (*2–7*). The careful observation of a dosing sequence interaction between Tc-99m sodium pertechnetate and Tc-99m pyrophosphate led to the serendipitous discovery of an in vivo labeling technique (*8,9*). Although the in vivo procedure provides excellent labeling results, it requires two direct venipuncture injections, one of stannous pyrophosphate and one of Tc-99m sodium pertechnetate.

Figure 1 illustrates the subnormal labeling efficiencies associated with administration of stannous pyrophosphate and Tc-99m sodium pertechnetate via heparinized catheter systems. After injecting tin chloride and pertechnetate through the catheter, the intense activity in the catheter results in less activity in the blood pool. In addition, the normal catheter position can overlie the heart, and intense activity in the catheter can interfere with imaging and has at times precluded any cardiac imaging.

Figure 2 illustrates the blood pool activity obtained from the in vitro labeling procedure we have discussed. Labeling RBCs with this technique consistently provides greater than 90% of the circulating activity in the RBC fraction. A similar technique has been proposed for all routine labeling of RBCs (*10*).

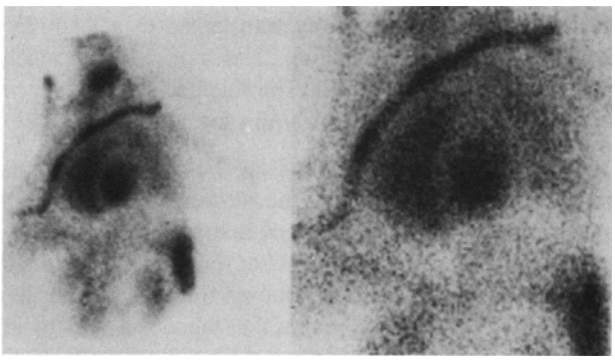

FIG. 1. Left anterior oblique image obtained after administration of stannous pyrophosphate followed by Tc-99m sodium pertechnetate through heparinized Hickman catheter.

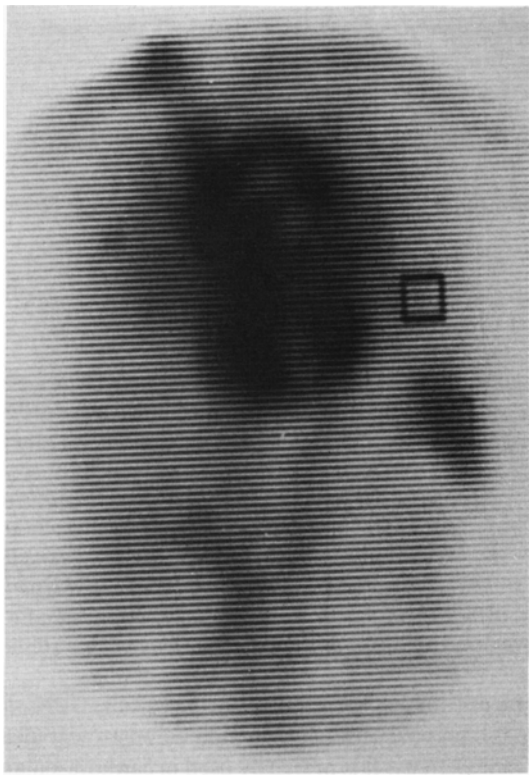

FIG. 2. Left anterior oblique image obtained after administration of Tc-99m RBCs labeled by in vitro procedure.

Although the RBCs were subjected to extensive manipulation, they were not seriously damaged as indicated by the relatively low splenic localization. We have never observed localization of activity in the catheter after using the in vitro tagging method.

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