Rose Protocol: Transcatheter pressure monitoring to assure hemodynamic effect and to quantify a hemodynamic endpoint for embolization

Steven C. Rose · Rachel Schrader

1 OVERVIEW

This protocol provides set-up instructions for the transcatheter pressure monitoring configuration shown in Figure 1. Additionally, this protocol explains how pressure measurements are taken and interpreted.

With this transcatheter pressure monitoring method, one can accurately compare systemic blood pressure (BP) with the pressure at the tip of the microcatheter with balloon occlusion to determine:

1) if the microcatheter is adequately occlusive
2) if blood flow will be directed into the downstream vascular compartment from adjacent vascular compartments to provide antegrade protection from nontarget embolization and likely increase the proportion of embolic delivery into the tumor
3) a potential hemodynamic endpoint for embolization

This method uses two transducers to allow for simultaneous comparison of the systemic blood pressure with the pressure at the tip of the microcatheter with balloon occlusion. Given the patient’s BP will change moment to moment, simultaneous comparison is important for accuracy and to mitigate measurement artifacts.

Keywords: Chemoembolization · Radioembolization · Embolization Endpoint · Embolization · Pressure-directed · Balloon occlusion

S. C. Rose (✉) · R. Schrader

Department of Radiology 8756, UCSD Medical Center, University of California, San Diego Health Sciences, 200 West Arbor Drive, San Diego, CA 92103-8756, USA
E-mail: scrose@ucsd.edu

©EmboliX, Inc. 2019. MK-0327-03 Rev. A
2 SET-UP

2.1 ITEMS NEEDED FOR SET-UP

<table>
<thead>
<tr>
<th>QUANTITY</th>
<th>ITEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>☐ 1</td>
<td>Embolx Sniper® Balloon Occlusion Microcatheter</td>
</tr>
<tr>
<td>☑ 2</td>
<td>Edwards LifeSciences™ TruWave™ Disposable Pressure Transducer (PX272)</td>
</tr>
<tr>
<td>☐ 2</td>
<td>Reusable Edwards LifeSciences Transducer to bedside monitor cable (PX1800). Contact Edwards Lifesciences for the specific cable version to connect a TruWave transducer to your bedside monitor model</td>
</tr>
<tr>
<td>☐ 1</td>
<td>Reusable IV pole mount for Edwards LifeSciences TruWave Disposable Pressure Transducer (TCLIP05)</td>
</tr>
<tr>
<td>☐ 1</td>
<td>3-way stopcock</td>
</tr>
<tr>
<td>☐ 4</td>
<td>20 ml syringe filled with saline</td>
</tr>
<tr>
<td>☐ 1</td>
<td>Laser level</td>
</tr>
</tbody>
</table>

2.2 SET-UP PROCEDURE

1. Set-up two (2) Edwards LifeSciences TruWave Disposable Pressure Transducers (Figure 2):
   a. Open on the sterile field two (2) TruWave Pressure Transducers.
   b. Disconnect tubing lines from transducers. Each transducer is packaged with two (2) lines connected: one line has a vent spike; the other line has a 3-way stopcock.
   c. Discard two (2) spike vent lines.
   d. Save two (2) transducers for later use.
   e. Save two (2) saline lines with 3-way stopcocks for later use.

![Figure 2: Pressure Transducer Set-up](image-url)
2. Set-up two (2) 20 ml syringes (Figure 3):
   a. Open on the sterile field two (2) 20 ml syringes.
   b. Fill both syringes with saline, label one SHEATH and the other MICROCAT.
   c. Attach the first 20 ml syringe filled with saline to a 3-way stopcock on a saline line from step 1e.
   d. Attach the second 20 ml syringe filled with saline to the remaining 3-way stopcock on the other saline line from step 1e.

![Figure 3: 20 ml flush syringe set-up](image)

3. Set-up two (2) transducers (Figure 4):
   a. Clip the transducer mount firmly onto IV pole.

   **IMPORTANT!** Use an IV pole originating on the procedure table because when the patient table moves up or down, it is important that the transducer location relative to the patient is maintained.

   b. Label one transducer “SHEATH” and other “MICROCAT”

   c. Fill two (2) 20 ml syringes with saline.

   d. Attach the first 20 ml syringe filled with saline to a transducer from step 1d.

   e. Attach the second 20 ml syringe filled with saline to the remaining transducer from step 1d.

   f. Mount two (2) transducers with 20 ml syringe filled with saline to transducer holder on IV pole with the transducer connection cables hanging down.

   g. Connect two (2) sterile saline lines from step 2 to both transducers.

   h. Discard the white caps on both transducer 3-way stopcocks.

   i. Connect both transducer connection cables to two bedside monitor cables. Connect the bedside monitor cables to the appropriate bedside monitor ports.

![Figure 4: Transducer set-up](image)
4. Position and level the two transducers to the patient’s mid-axillary line and 4th intercostal space (Figure 5):
   a. Move IV pole forward or backward on the patient’s table until the transducers are positioned at the patient’s 4th intercostal space.
   b. Using a laser level, slide the transducers up or down on the IV pole into position so that they are level to the patient's mid-axillary line while maintaining position at the patient’s 4th intercostal space.

**IMPORTANT!** The laser level should be aligned with the top of the 3-way stopcocks on the transducers.

**IMPORTANT!** The transducers must be exactly positioned to ensure accurate pressure readings.

![Figure 5: Exact positioning of the two transducers](image)

5. Figure 6):
   a. Turn 3-way stopcocks on both transducers open to air (pointed up as shown in Figure 4)
   b. Label the transducers on the monitor: “MICROCATH” and “SHEATH”.
   c. ZERO both transducers by pressing the ZERO on the monitor.
   d. Set the scale on the monitor for both the MICROCATh and the SHEATH pressure measurements to a 150 scale or slightly greater than systolic blood pressure as measured on the noninvasive system.

![Figure 6: Bedside monitor set-up](image)

---

6. Connect the stand-alone 3-way stopcock, V5, to the end of the microcatheter saline line as shown in Figure 7.

7. Flush the saline lines from the transducers to a point just beyond valves V3 and V5 creating an air and bubble free continuous fluid column (Figure 7):
   a. With valves V3 and V4 in the "syringe off" position and V5 in the "embolic agent inject off" position, pull the snap tab on the transducer while simultaneously filling the saline lines using syringes S1 and S2. Tap the lines while holding them upright to work out any air bubbles.
   b. Move the 3-way stopcock to the "transducer off" position on valves V3 and V4 per motion marked A. This action keeps air from entering the lines towards the transducers.
   c. Use syringes S3 and S4 to flush residual air out of the open end of the saline lines. Tap the lines to work out air bubbles.
   d. Move the 3-way stopcock to the "saline line off" position on valve V5 per in motion marked B. This action keeps air from entering the microcatheter saline line.

   **IMPORTANT!** Check the entire configuration for air bubbles and line kinks which are the most-common problem when measuring pressure and can result in inaccurate readings. Pressure measurement requires a continuous fluid column.

8. Connect the saline lines to both the introducer sheath and the microcatheter (Figure 8).
   a. Connect sheath line to the introducer sheath per configuration shown in Figure 8.
   b. Connect microcatheter line to the microcatheter 3-way stopcock per configuration shown in Figure 8.
3 PRESSURE MEASUREMENT AND EMBOLIC AGENT DELIVERY

1. Measure and record pressures from both the introducer sheath and the microcatheter (Figure 8):
   a. Flush the sheath and microcatheter lines using syringes S3 and S4.
   b. Move the 3-way stopcock to the "syringe off" position on valves V3 and V4 per motion marked A.
   c. Record sheath pressure. Record microcatheter pressure. For each pressure measurement of the sheath and microcatheter lines, record the systolic, diastolic and mean pressures from the bedside monitor. Once embolic agent delivery commences, wait until BP pressure readings stabilize before measuring pressures.

2. Inject Embolic agent via the microcatheter with occlusion balloon inflated (Figure 9):
   a. Move the 3-way stopcock to the "transducer off" position on valves V3 and V4.
   b. Move the 3-way stopcock to the "saline line off" position on valve V5 for embolic agent injection.
Studies to date on transcatheter pressure monitoring to assure hemodynamic effect and to quantify a hemodynamic endpoint for embolization have been focused on the liver. Therefore, the following pressure measurement interpretation guidance is based on liver experience only. While this protocol could be utilized in organs outside the scope of the liver (e.g., kidney, prostate, pancreas, uterus), further study is to verify the hemodynamic effects of balloon occlusion in extra-hepatic organs, each with its own unique angioarchitecture.

As noted in the protocol, transducers are utilized to measure the systolic, diastolic, and mean systemic arterial blood pressure (referred to as SHEATH), and the systolic, diastolic, and mean downstream vascular compartment arterial blood pressure (referred to as MICROCAT). The systemic arterial blood pressure is measured directly through the side arm of the femoral artery sheath. The sheath should have an inner diameter that is at least one French larger than the outer diameter of the coaxial base catheter. Flushing the system vigorously with saline prior to each reading will help ensure fidelity of the measurements.

The blood pressure within the vascular compartment that is downstream from the microcatheter is measured directly through the lumen of the balloon mounted microcatheter. When the balloon is deflated, the downstream vascular compartmental blood pressure should closely approximate the systemic arterial blood pressure unless the microcatheter occupies a large portion of the arterial cross-sectional area or unrecognized upstream arteriospasm has occurred. When the balloon has been inflated to the point of arterial occlusion, the blood pressure in the downstream vascular compartment should be reduced by 20-50 mmHg relative to the systemic arterial blood pressure (1,2).

The systemic compartmentalized arterial pressure differential (SCAPD) = mean systemic arterial blood pressure (mmHg) minus the mean downstream vascular compartment arterial blood pressure (mmHg). When calculating the SCAPD, using the mean systemic and downstream blood pressures appears to be the most reliable pressure measurement. The systolic blood pressure has excessive statistical noise (variability), and diastolic blood pressure downstream may actually be higher than the systemic diastolic blood pressure (even before embolization) due to damping of the arterial wave form.

If the SCAPD is less than 20 mmHg, most likely the balloon is not occlusive. Additional inflation is indicated until an appropriate SCAPD has been achieved. Once a suitable SCAPD has been attained (typically in the order of 40 mmHg), then blood flow in hepaticoenteric arteries can be confidently assumed to flow hepatopetally, thus providing antegrade protection from nontarget embolization in addition to the designed retrograde protection.

As a result of the 20-50 mmHg SCAPD, blood flow enters the downstream vascular compartment not only through hepaticoenteric arteries, but also through hepatic artery-to-hepatic artery connections between neighboring hepatic segments. This results in reversal of downstream compartmental hepatic arterial blood flow due to collateral reconstitution. Essentially embolic agent is flushed out of the nontumorous hepatic tissues. Presumably the tumor is a separate vascular compartment, thus continues to fill with embolic agent. The net result, as supported by a number of reported investigations (2,3,4) is increased delivery of agent to the tumor and reduced delivery to nontumorous liver. Of note, if tumors receive competing arterial inflow from outside the downstream vascular compartment (i.e., “Watershed” tumors), then these results may be less predictable (5).

Use of an occlusion balloon during embolization confounds the visual fluoroscopic clues used to determine the end point of embolization. Specifically, the occlusion balloon dramatically reduces the forward blood flow velocity. In addition, by design, the occlusion balloon serves as a back stop to reversal of blood flow. As embolization progresses, particles occlude portions of the vascular compartmental microvasculature, thus raising the downstream resistance to blood flow. This increased downstream resistance results in progressive reduction in the SCAPD (6,7). The algorithm adopted by the UCSD team involves repeated intraprocedural measurement of SCAPD after each delivery of approximately 10% of the intended chemoembolization or Y90 radioembolization resin microsphere dose. Of note, Y90 glass microsphere doses cannot be partitioned. When relatively large volumes of liver are at risk (e.g., lobar delivery), data seems to support safety using a 70% relative reduction in SCAPD as an embolization end point (7). In cases with relatively small volumes of liver at risk (e.g., segmental or subsegmental delivery), then intentional over embolization may
be an effective means for increasing embolic penetration into tumor and dealing with “watershed” tumors. Detailed review of hemodynamic principals and preliminary clinical evidence has been presented [8].

As an example, Figure 10 shows the bedside monitor display at the first pressure measurement when the microcatheter’s balloon was initially inflated, balloon occlusion was achieved (e.g. 38 mmHg pressure difference), and embolic agent (drug eluting embolic with doxorubicin) injection has not yet commenced. Figure 11 shows the first and sixth pressure measurement recordings (see section 6 for the measurement spreadsheet) with calculated mean pressures, pressure difference (SCAPD) and percentage reduction of the SCAPD after delivery of approximately 60% of the intended dose of embolic dose.

5 REFERENCES


Appendix: Pressure Measurement Recording Spreadsheet

Rose
Protocol Pressure
Meas.
Record_Final.xlsx