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A Peripheral Vascular Treatment for Chronic Obstructive Pulmonary Disease

An emerging cardiovascular technology may offer an alternative treatment for COPD.

BY PROFESSOR STEFAN SACK

As cardiovascular physicians, we are all aware of the benefits of exercise; one of the most important is an improvement in cardiac reserve. Many of us think of gains in cardiac output as a phenomenon restricted to elite athletes who pursue rigorous training regimens, with the goal of giving their muscles more fuel, in the form of oxygen, for improved exercise performance. But what about the possibility of utilizing improved cardiac output to improve oxygen delivery in patients whose oxygen delivery is limited not by their heart, but by their markedly impaired lung function? Such is the intent of a new cardiovascular procedure: purposefully creating a percutaneous arteriovenous (AV) fistula.

An AV fistula could improve oxygen delivery by (1) increased mixed venous oxygen saturation, (2) a pulmonary vasodilation effect in response to the mixed venous O_2 saturation, (3) increased cardiac preload, which in turn increases stroke volume, (4) increased stroke volume and cardiac output, and (5) an increased cardiac output without a decrease in the content of arterial oxygen, which increases oxygen delivery to muscles and tissue.

There are some situations that might limit the ability of using an AV fistula to increase O_2 delivery, such as (1) preexisting pulmonary vascular disease, which limits the capacity to reduce pulmonary vascular resistance as would normally occur when cardiac output increases, and (2) left ventricle diastolic dysfunction (as evidenced by a high wedge pressure), which limits the ability of the left side of the heart to accommodate the increase in venous return.

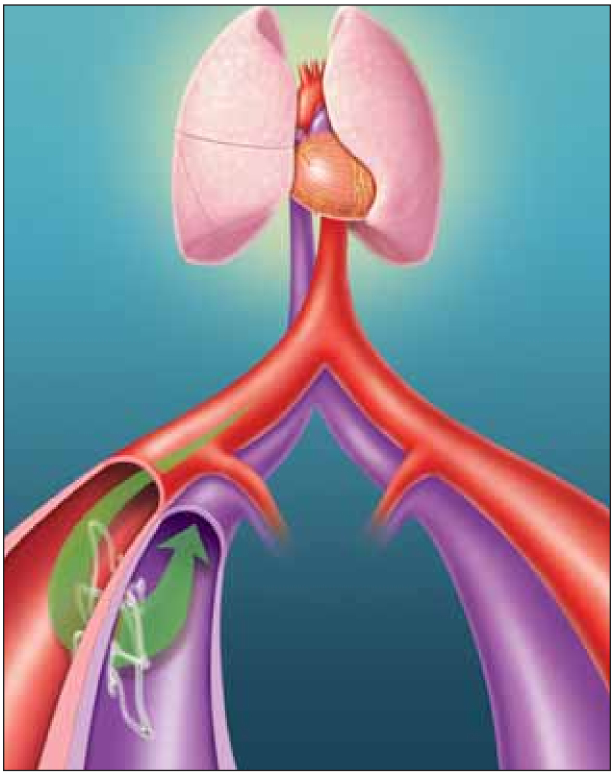

Figure 1. The ROX CO$_2$UPLER.

THE ROX FLO$_2$W PROCEDURE

The ability to percutaneously create an AV fistula via a side-to-side anastomosis of vein and artery is now possible by means of a new procedure developed by ROX Medical (San Clemente, CA) (Figures 1 through 3). In this procedure, the femoral vein is accessed via an 11-F sheath, and the femoral artery is accessed via a 4-F sheath. After placing introducer sheaths into the vein and the artery, a suitable location between the external iliac artery and vein is determined for the AV fistula. In order to determine a suitable location, a series of angiograms are obtained to ensure that the vessels are contiguous and that there is no calcification or plaque at the intended fistula creation site (Figure 4A).

To help provide constant visualization of the arterial structure, a nitinol guidewire, which retains a helical shape

Figure 2. First stage of the ROX CO_2UPLER deployment.

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after deployment, is tracked through the 4-F introducer and placed into the external iliac artery. The helical shape of the guidewire seats against the wall of the artery and provides real-time visualization of the arterial wall boundaries of the external iliac artery without repeated angiography and the associated additional contrast.

A proprietary crossing needle that has a curved shape with an inner 22-gauge cannula needle, is used to create a micropuncture from the vein into the artery (Figure 4B). Once the needle has been passed from the vein into the artery, a nitinol guidewire is tracked through the cannula needle, into the artery. The crossing needle is then removed, but the guidewire remains in place, between the vein and artery.

In order to maintain the size and stability of the fistula, a self-expanding nitinol implant is deployed between the vein and artery. The nitinol implant comes preloaded on an 8-F delivery system that tracks over the guidewire that was placed with the crossing needle. The catheter-based delivery system includes a nosecone to assist in dilation of the artery as the system (sheathed implant) is moved from the venous side to the arterial side. The initial stage of deployment is the unsheathing of two arterial stabilization arms and two clipping arms that will provide the first half of the structural support of the fistula. The second and third stages of deployment allow the release of the venous clipping arms, which essentially completes the clipping of the artery and vein together in a calibrated fashion, and the additional seating of the implant in the vein. A noncompliant angioplasty balloon is used to dilate the fistula against the inelastic arterial wall.

A final angiography run, after fistula dilatation, is performed to confirm a patent, well-placed fistula working as a calibrated shunt from artery to vein (Figure 4C). Angiography also confirms an absence of hemorrhage between the connected vessels. The calibrated size of the implant ensures a consistent flow rate of shunted blood volume, and the metallic structure of the implant supports the fistula in such a way as to avoid a distensible rim and derive long-term durability of established flow through the fistula. When the procedure is completed, the mechanical stability of the fistula and its calibrated size limit the flow and the change in cardiovascular hemodynamics to a prescribed and stable level.

DISCUSSION

One of the keys to understanding an AV fistula as a therapy for patients with advanced chronic lung disease is to recognize the effect that increased mixed venous oxygen saturation has on hypoxic pulmonary vasoconstriction. The redirected arterial blood not only raises the mixed venous oxygen saturation, the shunted flow also increases cardiac preload. The combination of increased preload and the accompanying pulmonary vasodilation significantly increases cardiac output and may benefit a substantial number of patients with severe chronic obstructive pulmonary disease by increasing their delivery of oxygen to muscle and tissues.

Thus, in patients with a significant pulmonary vasodilatory response to the increase in mixed venous oxygen content that accompanies creation of an AV fistula, the increased preload leads to an increased stroke volume and a rise in cardiac output. The increase in cardiac output occurs without an extreme "penalty" to the right side of the heart because the increased cardiac output has been facilitated, in part, by the reduction in pulmonary vascular resistance. However, if the patient's pulmonary vasculature cannot dilate appropriately, the opportunity to offset compromised delivery of oxygen to the tissues is foregone.

The sequence of hemodynamic changes accompanying the AV fistula can be summarized as follows. Immediately after creation of the fistula, the heart rate rises mildly to maintain systemic blood pressure in the face of the sudden drop in systemic vascular resistance caused by the AV fistula. But within a short period, blood volume increases, and the heart rate returns to prefistula values. Because preload increases as a result of the AV fistula, end-diastolic cardiac volumes must rise by at least a small amount, and stroke volume increases. This combination of physiological adaptations to the AV fistula leads to an increased cardiac output, in association with a stable ejection fraction. An average of 0.75 to 1 L of cardiac output passes through the fistula each minute, but in patients with a

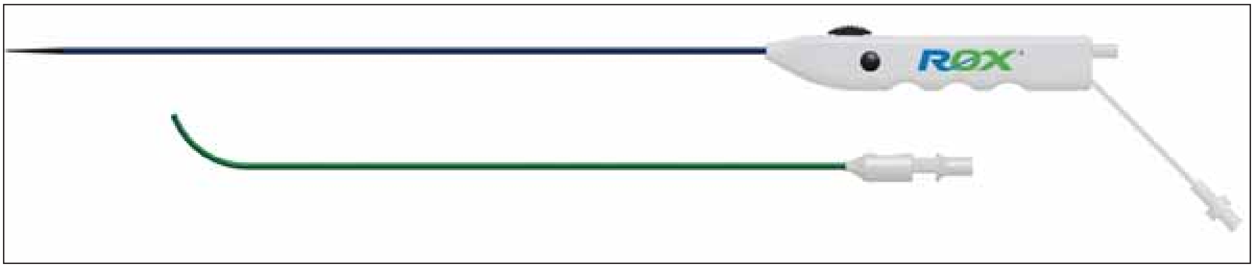

Figure 3. The single-use delivery catheter and ROX CRO$_2$SSING needle.

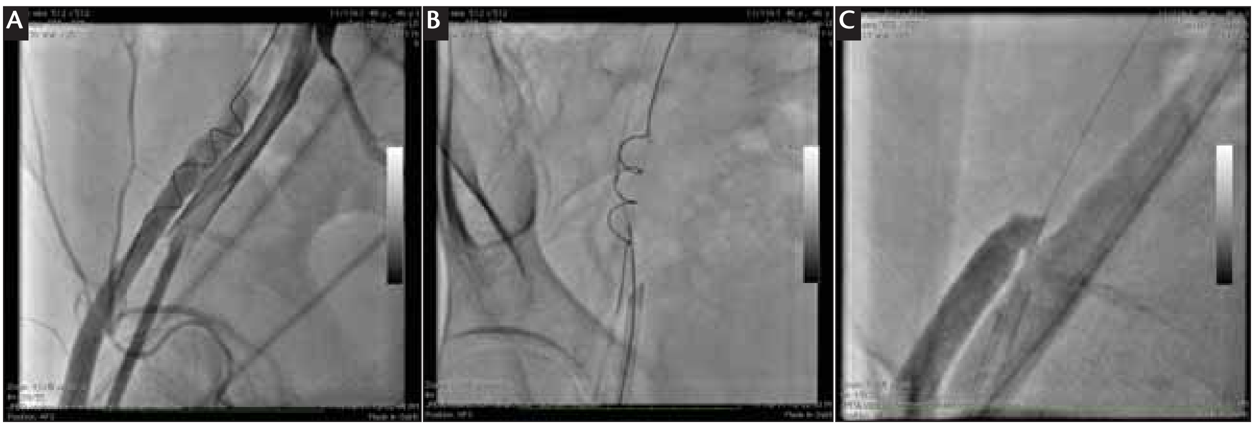

Figure 4. Visualization of parallel iliac artery and vein (A). Ninety-degree rotational view of vessels (iliac artery over vein) for needle crossing (B). Four-millimeter fistula creation after implantation of the ROX CO$_2$UPLER (C).

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marked drop in pulmonary vascular resistance, the increase in cardiac output is approximately twice that value, which means that greater blood flow and oxygen delivery is available to the exercising muscles.

Increasing venous return by means of an AV fistula can lead to venous stenosis and resulting edema, even with the use of compression stockings. A venogram should be obtained to evaluate suspected stenosis and, if necessary, a self-expanding nitinol stent can be placed to restore venous blood flow. In selected patients, an additional procedure may be necessary to mitigate the effects of the fistula; an arterial stent graft can be used to cover, or essentially close, the fistula, which restores venous flow to the initial prefistula levels.

CONCLUSION

Patients with symptoms and exercise limitation caused by severe chronic obstructive pulmonary disease may benefit from a cardiovascular intervention—the percutaneous creation of an AV fistula by means of a self-expanding nitinol device that creates a shunt by coupling a central vein and artery together, leaving a calibrated left-to-right shunt—as opposed to a lung intervention. Patients with a mean pulmonary arterial pressure > 35 mm Hg and patients with a pulmonary wedge pressure > 15 mm Hg are likely not good candidates. For patients to experience a meaningful increase in the delivery of oxygen, pulmonary vascular resistance must decrease. If a patient's pulmonary vascular resistance does not decrease, a second percutaneous procedure can be used to close the fistula and reverse the physiological effects. ■

Disclaimer: The ROX Anastomotic Coupler System is CE Marked for use with COPD patients. The ROX CO$_2$UPLER is not FDA approved and not available for sale in the United States. An FDA approved Clinical Study is ongoing in the United States under an Investigational Device Exemption (IDE). ROX Medical supports activities and data collection associated with a Patient Registry in Germany.

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