Dialysis Access Flow Phenomenon Demonstrated *via* an Internal Jugular Central Venous Catheter Uniquely Positioned within a Superior Vena Cava Stenosis

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RIGHT internal jugular vein central venous catheter placement is routine for cadaveric renal transplantation to assist intraoperative assessment of cardiac preload and intravascular volume status.[1] The presence of a surgical upper extremity arteriovenous fistula for hemodialysis can significantly alter flow patterns in regional vessels and both the arterial and venous circulation.[2] This can be compounded by variations in venous anatomy. Many patients with end-stage renal failure who advance to hemodialysis *via* an arteriovenous fistula have a period of dialysis *via* a tunneled central venous catheter often in the internal jugular vein. Central venous stenosis and thromboses are frequent complications of prolonged and repeated central venous access in hemodialysis patients.[3–5]

The authors report a case of concomitant arterial and venous pressure waveforms with correlating blood gas analysis measured *via* adjacent ports of a double lumen internal jugular venous catheter placed for cadaveric renal transplantation that was uniquely positioned within a superior vena cava stenosis.

CASE REPORT

A 62-yr-old woman with end-stage renal disease attributed to diabetic nephropathy presented for cadaveric renal transplantation. Other medical problems included hypertension, a nonspecific hypercoagulable state with previous deep vein thrombosis, peripheral vascular disease, and mild obesity with a body mass index of 30 kg/m². Significant surgical history included two previous right and two previous left tunneled internal jugular hemodialysis catheters; the last placed 2 yr previously. She also had a thrombosed left forearm arteriovenous fistula (AVF) and a functional right basilic vein to brachial artery AVF proximal to the antecubital fossa, which served as the site for active hemodialysis access. She had no history of significant limb ischemia related to her dialysis access.

General endotracheal anesthesia was achieved using propofol, fentanyl, and cisatracurium, and maintained with sevoflurane in an air/oxygen mixture. The right internal jugular vein was accessed using Seldinger technique and real-time ultrasound guidance. This required multiple attempts due to difficulty advancing the guidewire. Before vessel dilation, pressure was transduced by gravity using the technique described by Fabian and Jesudian[6] and was noted to be venous. This technique uses an 18-gauge angiocatheter in the right internal jugular vein (RIJ) connected to 50-cm extension tubing. Blood is withdrawn with a syringe vertically and a descending column of nonpulsatile flow should be observed in the tubing to confirm venous placement. Ultrasound was not used to confirm venous position of the guidewire. An Arrow® 8 French, 16 cm, double lumen 14-gauge catheter (Teleflex Medical, Triangle Park, NC) was then successfully placed, and each lumen was aspirated and flushed.

At the time of incision, a standard pressure transducer was connected to the proximal central venous catheter (CVC) port and an arterial waveform was noted with a mean pressure that was significantly below systemic pressure measured by cuff on the left upper extremity (fig. 1). For further evaluation, the transducer was then connected to the distal port and exhibited a typical venous waveform with a lower mean pressure (fig. 1). The monitor images shown in figure 1 were captured at the conclusion of surgery, but accurately represent the values observed at this moment of the procedure.
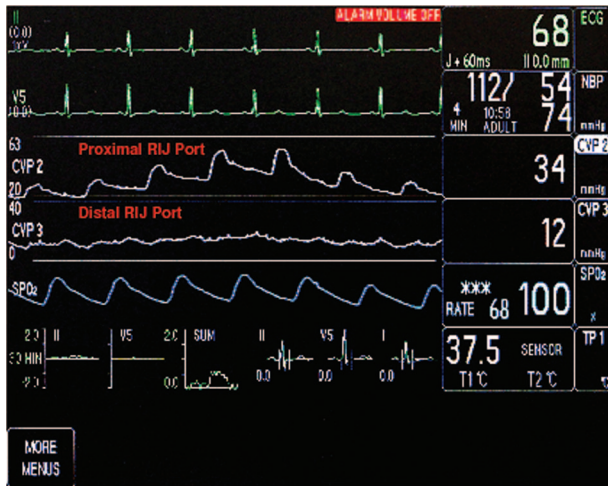
Fig. 1. Monitor photo demonstrating arterial (proximal) and venous (distal) waveforms within a double lumen right internal jugular (RIJ) vein central catheter placed within a superior vena cava stenosis.

Fig. 2. Monitor photo demonstrating arterial (proximal) and venous (distal) waveforms within a double lumen right internal jugular (RIJ) vein central venous catheter placed within a superior vena cava stenosis, after manual occlusion of the right upper extremity hemodialysis arteriovenous fistula.

Blood gases were analyzed from each lumen and presented in table 1. From the proximal lumen with an arterial waveform the partial pressure of oxygen (pO_2) was 184 mmHg at a fractional inspired oxygen concentration of 0.58, similar to what could be expected from an arterial sample. From the distal port with a venous waveform the pO_2 measured 68 mmHg at the same fractional inspired oxygen concentration. This was considerably lower than the proximal sample and closer to an expected venous value despite an only 2- to 3-cm distance between the ports.

An anteroposterior chest radiograph was obtained and showed the catheter in the expected location of the superior vena cava (SVC). Subsequently, we manually occluded the patients' right brachial AVF with external pressure and observed dampening of the proximal arterial waveform with a significant drop in the measured pressure (fig. 2). This technique is described by Angaramo *et al.*, to rule out intraarterial placement of an introducer sheath in the setting of an ipsilateral upper extremity AVF.[7] We concluded the line was indeed within the venous system despite the unusual pressure tracings.

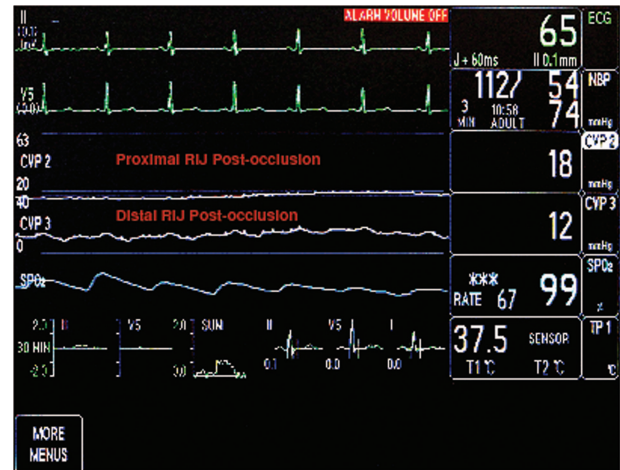We suspected that the central line could be positioned within a narrow portion of the SVC with the proximal and

distal ports on opposite sides of a stricture. The arterial waveform and blood gas value measured *via* the proximal port was the result of strong arterial flow transmitted from the patient's right upper extremity fistula. The venous pressure tracing and corresponding venous blood gas below the suspected narrowing indicated minimal communication between these hydrodynamic systems.

At the conclusion of surgery fluoroscopically-assisted venograms were obtained by injecting a small volume of contrast into each lumen and confirmed a SVC stenosis located precisely between the two ports of the catheter, thus explaining the unique physiologic scenario (figs. 3 and 4).

Five blood gases were then measured with a fractional inspired oxygen concentration of 0.80: an arterial control from the iliac artery on the surgical field, one from each of the central line ports with the AVF unoccluded, and one from each of the central line ports after 3 min of manual occlusion of the fistula (table 2). These results were consistent and confirmed the observed physiology.

The patient was successfully extubated in the operating room, the line was eventually removed, and she was discharged on postoperative day 3 with adequate graft function after an uncomplicated clinical course. We educated her about the stenosis and its relevance to any future symptoms.

Table 1. Blood Gas Analysis

	Proximal CVC Lumen	Distal CVC Lumen
pO_2 (mmHg)	184.4	68.9
pCO_2 (mmHg)	31.6	39.0
pH	7.52	7.50
HCO_3 (mM)	25.3	25.1
O_2 Sat (%)	99.6	94.7

F_{IO_2} = 0.58 (initial blood gases at start of surgery).

CVC = central venous catheter; F_{IO_2} = fractional inspired concentration of oxygen; HCO_3 = serum bicarbonate in millimoles per liter; O_2 Sat = calculated oxygen saturation; pCO_2 = partial pressure of carbon dioxide; pO_2 = partial pressure of oxygen.

Discussion

Complications of AVF for hemodialysis include thrombosis, infection, aneurysm, and congestive heart failure.[8] Central venous stenosis and thromboses are frequently observed in hemodialysis patients with prolonged and repeated central venous access.[3–5] Dialysis access flow phenomenon is well described, wherein high-pressure arterial blood is shunted to the lower pressure venous system and may result in venous hypertension, heart failure, and limb ischemia.[9] This case represents a physiologic demonstration of this phenomenon
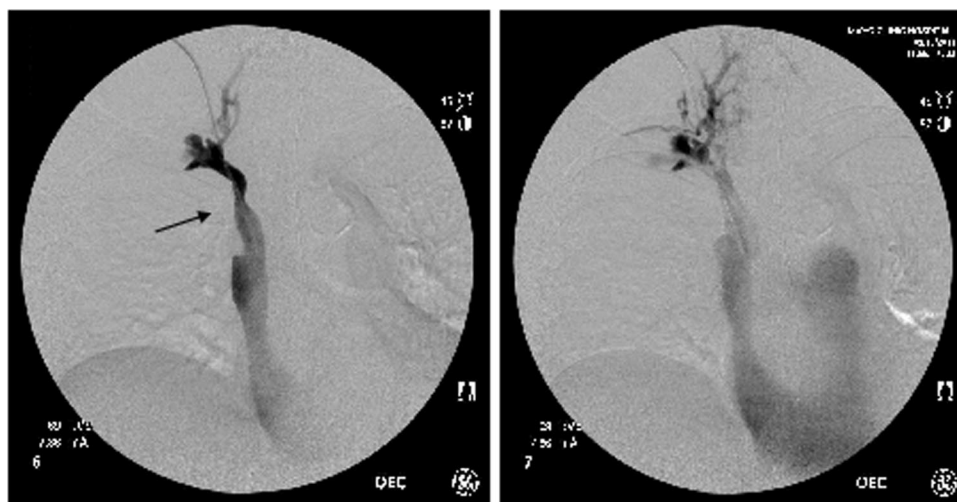
Fig. 3. Venograms obtained *via* injection into the proximal central venous catheter port demonstrating superior vena cava stenosis (*arrow*) and time delayed reflux of contrast cephalad into venous circulation.

that was captured due to unique positioning of a central venous catheter.

In the setting of a brachial artery to basilic vein AVF, arterialization of venous blood in the regional circulation is expected. The presence of an ipsilateral right upper extremity AVF should be recognized when placing a RIJ CVC because pressures may be increased, although it is not a contraindication to placement. Yee and Despotis demonstrated partial arterialization in the setting of an ipsilateral high-output upper extremity AVF *via* two separate RIJ "double stick" catheters placed at different locations using blood gas analysis, although no pressure or waveform data were presented.[10]
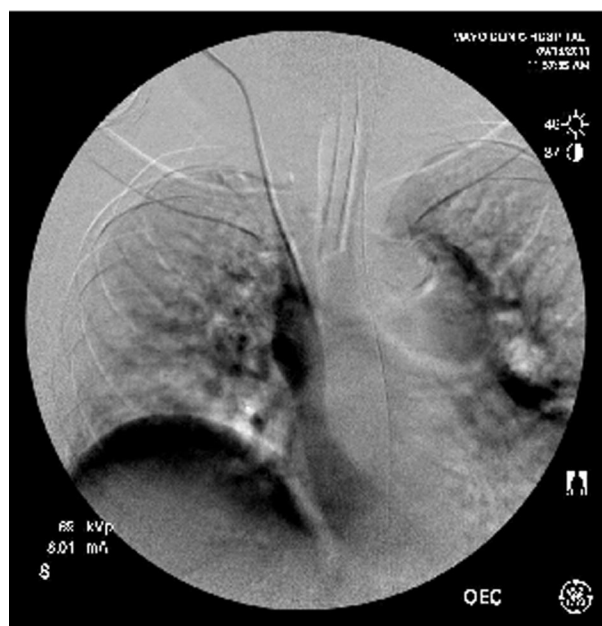

Fig. 4. Venogram obtained *via* injection into distal central venous catheter port, beyond the superior vena cava stenosis, demonstrating free passage of contrast into the pulmonary circulation.

In our case the typical brachial arterial waveform[11] produced from the proximal RIJ port (fig. 1) has no venous waveform distortion despite its sizable distance from the upper extremity fistula. The mean pressure is significantly reduced compared with systemic pressure, 34 mmHg *versus* 74 mmHg, indicating attenuation of pressure despite complete preservation of the waveform. Arterial waveform purity was likely evident due to the SVC stenosis causing a pressure gradient that was then intensified by the presence of a space occupying catheter. The net result was unique separation of venous and arterial flow dynamics above and below the focal stenosis within a 2- to 3-cm distance.

We considered other possibilities in our differential diagnosis when confronted with the unexpected arterial waveform. It was plausible that the catheter was placed in an artery with only the distal tip migrating into the central venous system. Or conversely, there could be a *de novo* arteriovenous communication near the distal tip of the catheter, which could explain our observations. Stepwise investigation of the catheter position diminished the likelihood of these scenarios and emphasizes the systematic process of troubleshooting a potentially malpositioned catheter.

When first viewing the arterial waveform from the proximal port of the central catheter we immediately verified the result by examining the distal port waveform. When this exhibited a venous waveform, blood gases from each lumen at fractional inspired oxygen concentration of 0.58 were immediately drawn and verified an arterial *versus* venous discrepancy (table 1). After a chest radiograph confirmed the expected position, our next maneuver was to occlude the upper extremity fistula with manual pressure.[7] This completely eliminated the arterial tracing from the proximal CVC port and caused significant reduction in mean pressure from 34 mmHg to 18 mmHg, whereas the distal port read 12 mmHg (fig. 2). If the catheter was in an artery, or if there was a *de novo* nonsurgical fistula near the SVC, this would not

Table 2. Blood Gas Analysis

	Left External Iliac Artery	Proximal CVC Preocclusive	Distal CVC Preocclusive	Proximal CVC Postocclusive	Distal CVC Postocclusive
pO$_2$ (mmHg)	251.6	258.1	75.8	51.3	54.5
pCO$_2$ (mmHg)	30.2	33.7	38.4	44.3	45.0
pH	7.49	7.47	7.43	7.39	7.38
HCO$_3$ (mM)	22.3	24.0	25.8	25.9	26.1
O$_2$ Sat (%)	99.8	99.8	95	85.1	86.7

F$_{IO_2}$ = 0.80 (obtained at conclusion of surgery).

CVC = central venous catheter; F$_{IO_2}$ = fractional inspired concentration of oxygen; HCO$_3$ = serum bicarbonate in millimoles per liter; O$_2$ Sat = calculated oxygen saturation; pCO$_2$ = partial pressure of carbon dioxide; pO$_2$ = partial pressure of oxygen; postocclusive = values obtained after manual compression of arteriovenous fistula; preocclusive = values obtained before manual compression of arteriovenous fistula.

have occurred. We cannot overemphasize the importance of this maneuver as an initial intervention to decrease concern of a carotid artery cannulation and identify the source of arterial blood. Despite reassurance of a venous catheter position, we sought to explore our hypothesis that the dramatic pressure, waveform, and blood gas differences were due to a stricture.

The second series of blood gases obtained at a fractional inspired oxygen concentration of 0.80 at the conclusion of surgery further defined and verified the arterial *versus* venous separation (table 2). Because we did not have a radial arterial line in place we obtained a control sample from the external iliac artery on the surgical field. This was compared with a preocclusion value from the proximal CVC port. The pO$_2$ was actually higher from the proximal CVC at 258.1 mmHg, *versus* 251.6 mmHg from the iliac artery, with the pH and oxygen saturation values nearly identical. Both were clearly arterial-like. The blood gas from the preocclusion distal CVC with a central venous waveform had a pO$_2$ of 75.8 mmHg, indicating significant venous mixing.

We estimated 3 min of manual compression as enough time to allow blood gas samples from both CVC lumens to equilibrate to venous levels. Samples were drawn and the pO$_2$ of these were similar at 51.3 and 54.5 mmHg, with pH, carbon dioxide partial pressure, and especially oxygen saturation values indicating correlating venous levels. This would not occur if any portion of the distal catheter was in an artery, or if there was another source of arterial blood in the venous circulation except the upper extremity AVF.

Venography clearly outlined the suspected focal SVC stenosis with significant contrast refluxing proximally into the venous circulation, and a small amount flushing distally into the pulmonary circulation (fig. 3). Injection into the distal port demonstrated free passage of contrast into the pulmonary circulation with no proximal reflux (fig. 4). We were convinced that our diagnosis was accurate and we were observing unique flow dynamics captured with the inadvertent position of a CVC. The 2- to 3-cm distance between the two ports of the CVC makes this observation even more striking.

This case represents a unique example of vascular flow dynamics in a patient with a hemodialysis AVF while raising awareness of several important principles in this patient population. First, central venous stenosis and thrombosis are common in hemodialysis patients. Second, the presence of a high-output AVF has a profound effect on regional and systemic vascular physiology. The combination of these two factors may have a significant effect on central venous catheter placement in the anesthesia setting. Finally, it highlights the systematic evaluation of a potentially malpositioned central venous catheter.

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