More may be less: increasing extracorporeal blood flow in an axillary arterio-arterial access decreases effective clearance

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Abstract
Axillary arterio-arterial graft interposition has been described as a reasonable haemodialysis access in selected patients. In a patient with this unusual access, we measured and calculated effective clearance at different extracorporeal blood flows ($Q_b$). Effective clearance increased with increasing blood flow and reached a maximum at a $Q_b$ of $\sim 200$ mL/min but then decreased when $Q_b$ was increased further. As this type of access typically provides low access flow, one has to be aware that local recirculation will easily occur. Therefore, a $Q_b$ above access flow has to be avoided since any increase beyond that threshold reduces effective clearance.

Keywords: arterio-arterial access; clearance; haemodialysis; recirculation

Background
An arteriovenous (AV) shunt preferably provided by a native fistula is the access of choice to deliver haemodialysis [1]. When the creation of a shunt is not feasible (e.g. exhaustion of vessels, impaired cardiac function), alternate solutions have to be explored, as prolonged use of tunneled central venous catheters (TCVCs) is discouraged [2]. Arterio-arterial graft interposition has been used as a successful long-term alternative in selected patients [3]. However, this unusual access bears some caveats due to its distinctive haemodynamics.

Case report
A lady aged 68 and on haemodialysis for 12 years due to diabetic nephropathy was admitted because of a septic TCVC in the right internal jugular vein. Antibiotic treatment was initiated and the catheter was removed. The patient had a history of multiple shunt thromboses with surgical as well as radiological interventions of AV-fistulas on both arms and bilateral central venous stenoses caused by repeated central venous catheterization. Furthermore, both lower legs had been amputated because of severe peripheral arterial occlusion disease. Bilateral thrombotic occlusion of internal jugular and subclavian veins as well as a sonographically undetectable right femoral vein required a new TCVC placed into the left femoral vein as the last venous resort. As this access is problematic in the long run [4] and the patient refused peritoneal dialysis, an alternative permanent access was warranted. Ultimately, an 8-mm Goretx loop was inserted into the right subclavian artery as an end-to-end anastomosis and placed subcutaneously above the pectoral muscle creating an arterio-arterial access as described elsewhere (Figure 1) [3]. The patient was continued on low-dose aspirin and the graft has now been in function for over 12 months without complications.

Access flow ranged between 144 and 184 mL/min. Extracorporeal blood flow ($Q_b$) was easily increased beyond that value. Three per cent access recirculation developed at a measured $Q_b$ of 190 mL/min, which further increased to 44% at a $Q_b$ of 262 mL/min. The increase in $Q_b$ led to an increase in effective clearance (max. 143 mL/min) only up to a $Q_b$ of $\sim 200$ mL/min. Any further increase in $Q_b$ beyond the threshold of developing access recirculation produced a decrease in effective clearance (Figure 2).

Discussion
An axillary arterio-arterial loop may provide long-term haemodialysis access; however, limited blood flows have
to be expected. In a normal axillary artery, a flow of \(\sim 190 \text{ mL/min}\) can be anticipated [6], which at best will remain in the same range after interposition of a loop graft. A comparable access flow was measured in our patient. Indeed, median access flow in 20 axillo-axillary arterial loop grafts was only 165 mL/min (55–250 mL/min) [3]. Even with correct needle placement, local recirculation must develop when \(Q_b\) exceeds access flow. Contrary to expectations, an increase in \(Q_b\) beyond the value determined by access flow not only fails to further increase extracorporeal clearance but actually decreases the clearance to lower levels than those seen at maximum \(Q_b\) without access recirculation. It is often erroneously assumed that effective clearance will reach a plateau in the presence of access recirculation and that an inadvertent increase in access recirculation by increasing \(Q_b\) above the level of access flow is compensated by increased \(Q_b\). Without going into the mathematical details described elsewhere [7], it is clear that effective clearance must decrease with increasing access recirculation because with 100% recirculation effective clearance will completely disappear. As demonstrated in Figure 2, the decrease in effective clearance can be measured by online clearance, which accounts for both access and cardiopulmonary recirculation. This characteristic is well known and has been described for single-needle dialysis [7] and can be used to detect access recirculation in AV fistulae [8]. It is not specific for arterio-arterial accesses. However, this information is especially important for this type of access where \(Q_b\) can be increased with little effort because arterial pressure provides additional energy to fill the extracorporeal circulation. Optimal \(Q_b\) could also be determined by a stepwise increase in \(Q_b\) accompanied by repeated recirculation measurements and to prescribe the maximum \(Q_b\) delivered without local access recirculation.

One has to be aware that with such low access flows, dialysis will have to last longer, e.g. in an average 70 kg patient (\(\sim 35 \text{ L total body water}\)) >5 h at a \(Q_b\) of 200 mL/min to achieve an unequilibrated \(Kt/V\) of 1.4.

With regard to patient haemodynamics and arterial pressures, the arterio-arterial configuration is similar to a central venous (veno-venous) access. It causes no or only little disruption as the blood is returned to the same compartment from which it is removed so that the pressure in that compartment is not affected [9]. Therefore, it may be an interesting option for patients with heart failure.

Some safety issues have to be considered. While it is convenient to administer medications intravenously during haemodialysis, many drugs which have the potential of inducing ischaemic injury if given intra-arterially—like opioids, tranquillizers, most antibiotics and possibly iron containing compounds—have to be avoided in this setting [10]. Obviously, access thrombosis could acutely endanger arterial blood supply to the affected extremity. Interestingly, only moderate hand ischaemia was described in a patient with early thrombosis, while late thromboses (>30 days) in three patients remained asymptomatic [3].

In conclusion, an arterio-arterial graft is a reasonable option for selected haemodialysis patients. However, one has to be aware that local recirculation will easily occur in such a low-flow access in spite of acceptable arterial line pressures. Prescription of \(Q_b\) above the threshold of developing access recirculation has to be avoided since dialysis efficiency will deteriorate. Repeated measurements of recirculation and online clearance are helpful to prescribe optimal \(Q_b\). Longer
than usual treatment times may be needed in order to achieve adequate dialysis dose in this unusual access.

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References

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