PRESSURE-CONTROLLED PERFUSION

The relationship between pressure and flow in the vasculature can be conveniently described by a modified version of Ohm's law. As it applies to the circulation, this equation is **P = Q * R**, where P is the pressure head driving the blood through the vascular bed, Q is the flow, and R is the resistance of the vascular bed[1]. All currently available perfusion pump systems require the operator to select a desired flow rate. This design characteristic is problematic in its clinical application for a number of important reasons.

Limitations of Flow-controlled perfusion systems:

1. In the clinical setting, the resistance of any given vascular bed cannot readily or practically be estimated. As a result of this, as described in the equation above, by driving the system by selecting a specific flow rate, the operator has no control over the pressure that will develop within the patient's vasculature to produce the set amount of flow. Obviously then, if the flow is set too high for any given amount of vascular resistance, the pressure that develops can exceed safe levels and lead to serious adverse events such as embolization of atherosclerotic plaques, and even vessel rupture. Further, obviously, if the flow is set too low in an effort to avoid vascular complications, then this will not provide adequate perfusion to the target vascular bed, potentially resulting in continued ischemia or even infarction of the downstream tissues. These deficiencies of flow-controlled perfusion systems are clinically quite important because not only is it not possible to estimate any given patient's vascular resistance, but, as described next, the level of resistance varies widely between different individuals, and also varies widely in a given individual over time.

2. Inter-individual variability - There are quite large differences in vascular resistance between individuals. These differences are in part attributable to characteristics related to body size, sex, ethnicity, age, vascular disease, degree of conditioning, etc... As a result of this large degree of variability in vascular resistance, the appropriate flow rate that would be required to adequately perfuse a given vascular bed without causing dangerously high pressures will vary considerably between individuals, and importantly, cannot be determined in any way at the bedside.

3. Intra-individual variability - In addition to the large effects of differences between individuals, the resistance of any given vascular bed within an individual is quite dynamic and can vary widely over time[2]. For example, when an ischemic limb is initially re-perfused, the vascular resistance in that limb will be extremely high because of the many metabolic derangements that are associated with the ischemia. Shortly after reperfusion, the vascular resistance will fall dramatically as the accumulated waste products of the previously ischemic limb are washed out, and as the vasculature adapts to accept as much blood as quickly as possible. Finally, following this washout period, the resistance will return to a more moderate level. Throughout these dynamic changes, if a constant flow is provided, as is the case with a flow-controlled system, the intravascular pressure will swing proportionately with the changes in vascular resistance, potentially again resulting in either dangerously high pressures, or inadequate perfusion. Again, the operator has minimal tools at the bedside to assess these changes and to manually adjust the set flow to both effective and safe levels. In order to utilize a flow-controlled system such as this in as safe a manner as possible, the operator is required to constantly monitor pressure in the perfused limb manually, and then manually adjust the set flow, a tedious and inefficient approach at best.

The solution to these problems is an intelligent pressure-controlled perfusion system.

It's interesting to note that, despite the huge variation in body size and body habitus, **virtually all mammals maintain normal blood pressures at remarkably similar levels** with systolic pressures in the range of 80-120 mmHg[3]. This, despite many orders of magnitude differences in body size. A pressure-controlled perfusion system takes advantage of this natural phenomenon by monitoring intravascular pressure in the perfused vascular bed, and intelligently regulating the flow provided to maintain the vascular pressure within a safe range. In this way, regardless of differences in the vascular resistance between individuals, or changes that occur over time in any given individual, the target vascular bed will accept whatever flow is safe and appropriate based on its own vascular resistance at any given time.

1. https://www.ncbi.nlm.nih.gov/books/NBK470310/#:~:text=Pressure%20differences%20in%20the%20form,Q%20%3D%20ΔP%2FR
2. https://link.springer.com/chapter/10.1007/978-4-431-68078-9_34
3. https://www.physoc.org/magazine-articles/on-the-blood-pressure-of-mice-and-men/