Clinical monitoring of peripheral perfusion: there is more to learn

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See related research by He et al, http://ccforum.com/content/17/3/R116

Abstract

Irrespective of initiating factors, the peripheral circulation shows two general phases during the development and treatment of shock. Most published reports support earlier knowledge that the peripheral circulation is among the first to deteriorate and the last to be restored. With the advent of new and old techniques that allow us to continuously monitor peripheral perfusion, we may further shift our focus from pressure-based to flow-based resuscitation. The persisting challenge is the validation (effect on outcome parameters) of peripheral perfusion monitoring tools that can be simple and readily available worldwide.

Despite enthusiasm raised by new hemodynamic monitoring systems, a large gap still exists between what we can measure and what we would really like to measure. The report in a previous issue of Critical Care by He and colleagues on two techniques for peripheral perfusion monitoring adds new insights into this topic [1]. In patients with septic shock, they studied the use of continuous transcutaneous oxygen, carbon dioxide tension and peripheral perfusion index (PI) derived from the pulse oximetry signal. Although these are not new technologies, their study highlights the importance of the status of nonvital organ perfusion in the resuscitation of patients with circulatory shock.

Earlier observations on the behavior of nonvital organ perfusion have shown two phases during the shock state, irrespective of initiating factors [2]. During the initial phase, compensatory mechanisms predominate to preserve the perfusion of vital organs at expense of the peripheral tissues (nonvital organs). As blood flow variations in this phase follow a similar response pattern in the skin, subcutaneous tissue, muscle and gastrointestinal vascular beds, these tissues are highly sensitive for detecting occult tissue hypoperfusion during compensated circulatory shock. Although these are functionally and metabolically different organs, at a functional circulatory level they are remarkably similar. Blood flow in these organs is moderately to strongly influenced by sympathetic vasoconstrictor mechanisms. In this regard, coronary, cerebral, and renal circulations show a high degree of autoregulation with poor sympathetic control, whereas skeletal muscle, gastrointestinal and cutaneous circulations show a predominant sympathetic control with a poor degree of autoregulation. With the progression of circulatory shock and following initiation of therapy and normalization of systemic hemodynamic parameters, the association between global flow and peripheral circulation becomes less striking and ultimately disappears. Some patients enter a phase where the physiological gap between macrocirculation and microcirculation becomes more evident and intricate(Figure 1). To what extent each peripheral vascular bed expresses hypoperfusion in these stages of shock remains to be investigated. Nevertheless, most published reports support our earlier knowledge that the vascular bed of peripheral circulation is among the first to deteriorate and the last to be restored after resuscitation and, therefore, through this being a window of perfusion [3].

Poeze and colleagues observed that global hemodynamic variables and gastric tonometry variables were both different between survivors and nonsurvivors, and no superior predictor of outcome was identified at admission before ICU resuscitation was initiated [4]. However, after stabilization and normalization of global hemodynamics, gastric tonometry variables were the best predictor of outcome. Other studies have reported similar time courses in different peripheral vascular beds, such as skin, muscle and sublingual microcirculation. These studies showed that persistence of abnormal peripheral perfusion following restoration of global hemodynamics was related to an unfavorable outcome [5-9]. Our group evaluated changes in
parameters of skin and muscle perfusion during early re-
suscitation of circulatory shock [8,9]. We found that pa-
tients who failed to normalize their capillary refill time, PI
and peripheral tissue oxygenation during early treatment
had a worse outcome. These findings could have implica-
tions for the treatment of critically ill patients with persist-
ent abnormal peripheral perfusion, requiring additional
diagnostic or therapeutic interventions.

He and colleagues explored the relationship between
global and peripheral perfusion variables following initial
resuscitation in septic patients [1]. The authors used two
distinct but complementary methods to evaluate periph-
eral perfusion (PI and transcutaneous oxygen/carbon di-
oxide tension). The PI calculates the ratio between the
arterial compartment and the nonpulsatile component
and because the size of the pulsatile portion increases
with vasodilation and decreases with vasoconstriction,
changes in the PI reflect changes in peripheral blood
flow. Transcutaneous oxygen/carbon dioxide tension, on
the other hand, is a measure of oxygenation, and is re-
lated to variations in local perfusion [10]. The authors
demonstrated that nonsurviving septic patients had poor
peripheral perfusion characterized by lower PI and a
blunted response to the oxygen challenge test (OCT; the
change in transcutaneous oxygen tension relative to the
change in arterial partial pressure of oxygen after 10 mi-
nutes on fraction of inspired oxygen of 1.0). The authors
also showed that the PI and OCT could predict mortality
with similar accuracy to arterial lactate levels, although
not corrected for confounding factors.

Interestingly, the study showed that both survivors and
nonsurvivors had abnormal peripheral blood flow, as
reflected by the lower PI values, when compared with
healthy controls. Even more interestingly, nonsurvivors had
significantly lower OCT values associated with higher ar-
terial lactate levels. Assuming that global hemodynamic
variables were optimized in all patients, the low OCT in the
nonsurvivors could be explained either by a high rate of
oxygen consumption or by decreased oxygen delivery, as
hypothesized by the authors. Since oxygen requirements of
the skin are quite low relative to other organs, we can
speculate variations in peripheral blood flow as the main
reason of low OCT in nonsurvivors, supported also by the
low PI values. These results underscore the context of the
peripheral circulation in septic shock, and provide evidence
of a heterogeneous distribution of blood flow in sepsis. This
phenomenon was first described by Gilbert in 1960 as ‘dila-
tion in one (vascular) bed might be accompanied by con-
striction elsewhere’ [11]. This statement is supported by the
findings of He and colleagues showing that peripheral vaso-
constriction can be a hallmark of early septic shock [1].
While these abnormalities in peripheral perfusion predict
an unfavorable outcome, it still needs to be proven that cor-
recting these abnormalities results in improved outcome.

As clinicians we start shifting our focus from monitor-
ing global pressures to monitoring flow and its determi-
nants in order to assess adequacy of resuscitation
[12,13]. With the advent of techniques that allow us to
continuously monitor peripheral perfusion, we could
further shift our focus to maintaining normal perfusion
in nonvital organs, such as skin, subcutaneous tissue and
muscle. The fundamental challenge is the validation of
low-cost peripheral perfusion monitoring tools that can
be readily available worldwide. The measurement of

![Figure 1 Clinical pattern of alterations in global and peripheral blood flow during circulatory shock.](http://ccforum.com/content/18/1/113)
transcutaneous and sublingual microcirculation at the bedside is still mostly used in larger research centers. Reliance on simple methods such as the capillary refill time, skin temperature, and PI must be emphasized and exploited. However, the true clinical implications of these tools should be better defined in clinical trials targeting peripheral perfusion.

Abbreviations
PI: Perfusion index; OCT: Oxygen challenge test.

Competing interests
The authors declare that they have no competing interests.

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