Capillary refill and core–peripheral temperature gap as indicators of haemodynamic status in paediatric intensive care patients

Shane M Tibby, Mark Hatherill, Ian A Murdoch

Abstract

Objectives—Capillary refill time is an important diagnostic adjunct in the acute resuscitation phase of the shocked child. This study assesses its relation to commonly measured haemodynamic parameters in the postresuscitation phase when the child has reached the intensive care unit, and compares this with core–peripheral temperature gap.

Methods—Ninety standardised measurements of capillary refill time were made on 55 patients, who were divided into postcardiac surgery (n = 27), and general (n = 28), most of whom had septic shock (n = 24). A normal capillary refill time was defined as ≤ 2 seconds. Measured haemodynamic variables included: cardiac index, central venous pressure, systemic vascular resistance index, stroke volume index (SVI), and blood lactate. Seventy measurements were made on patients while being treated with inotropes or vasodilators.

Results—Capillary refill time and temperature gap both correlated poorly with all haemodynamic variables among postcardiac surgery children. For general patients, capillary refill time was related to SVI and lactate; temperature gap correlated poorly with all variables. General patients with a prolonged capillary refill time had a lower median SVI (28 ± 38 ml/m²) but not a higher lactate (1.7 v 1.1 mmol/l). A capillary refill time of > 6 seconds had the best predictive value for a reduced SVI.

Conclusion—Among ventilated, general intensive care patients, capillary refill time is related weakly to blood lactate and SVI. A normal value for capillary refill time of ≤ 2 seconds has little predictive value and might be too conservative for this population; septic shock

Keywords: capillary refill; cardiac output; stroke volume; hypovolaemia; septic shock

Measurement of capillary refill time is said to be a quick, reproducible method for assessing a patient's circulatory status. It is used, in conjunction with other clinical signs, in both UK (advanced paediatric life support; APLS) and USA based (paediatric advanced life support; PALS) teaching programmes as a tool for demonstrating shock and as a guide to the effectiveness of resuscitation.1–2 With the drive for formalisation of paediatric resuscitation teaching for junior doctors,1–4 capillary refill time has come to occupy centre stage in the assessment of shock as a consequence of hypovolaemia, myocardial insufficiency, or a combination of both. Concern regarding the suitability of this measurement for “in the field assessment” has resulted in its withdrawal from the adult trauma score,3 and questions have been raised over it’s ability to detect hypovolaemia in adults.5 In addition, very little is written about the usefulness of capillary refill time in the postresuscitation phase, when the critically ill patient has reached the intensive care unit. It is our impression that a multitude of other factors come into play at this stage, making the interpretation of capillary refill time difficult. With this in mind, we aimed to investigate the relation between capillary refill time, hypovolaemia (as measured by central venous pressure), and commonly used indices of adequacy of blood flow (cardiac output, stroke volume, systemic vascular resistance, and blood lactate) in paediatric intensive care patients. In particular, we wished to assess if a prolonged capillary refill time (≥ 2 seconds) could reliably predict inadequate blood flow. Lastly, we intended to evaluate whether a similar relation exists between a parameter commonly recorded in the intensive care unit, core–peripheral temperature gap, and the aforementioned haemodynamic variables.

Subjects and method

Capillary refill time was measured in ventilated patients in whom invasive haemodynamic monitoring was instituted for clinical reasons. Ninety measurements were made on 55 patients who were subdivided into two groups: postcardiac surgery (n = 27), and general (n = 28). Demographic data are shown in table 1. Twenty four of the 28 patients in group 2 had septic shock; other diagnoses (all n = 1) were: multiorgan failure secondary to hypernatraemic dehydration, hypertrophic cardiomyopathy, nephrotic syndrome with pulmonary oedema, and bilateral subdural effusions associated with an apparent life threatening event.

Table 1 Demographic data

<table>
<thead>
<tr>
<th></th>
<th>Cardiac (n=27)</th>
<th>General (n=28)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total measurements (n)</td>
<td>44</td>
<td>46</td>
</tr>
<tr>
<td>Measurements on inotropes/vasoactive drugs (n)</td>
<td>27</td>
<td>43</td>
</tr>
<tr>
<td>Median (interquartile range) age (months)</td>
<td>30 (3.3–85)</td>
<td>41 (12–70)</td>
</tr>
<tr>
<td>Median (interquartile range) weight (kg)</td>
<td>11 (4.7–21)</td>
<td>15 (10–26)</td>
</tr>
</tbody>
</table>
Table 2  Formulae for haemodynamic variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Units</th>
<th>Formula</th>
<th>Normal range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cardiac index (CI)</td>
<td>l/min/m²</td>
<td>CI = cardiac output/body surface area</td>
<td>3.0–5.5</td>
</tr>
<tr>
<td>Systemic vascular resistance index (SVRI)</td>
<td>dyne/s/cm²/m²</td>
<td>SVRI = 79.9 × (mean arterial pressure – CVP)/CI</td>
<td>800–1600</td>
</tr>
<tr>
<td>Stroke volume index (SVI)</td>
<td>ml/m²</td>
<td>SVI = CI/heart rate</td>
<td>30–60</td>
</tr>
</tbody>
</table>

Exclusion criteria included conditions that would affect the accuracy of thermodilution measurements of cardiac index, such as anatomical shunts (confirmed by colour Doppler echocardiography), arrhythmias, or valvular regurgitation.

All measurements of capillary refill time were made by the same clinician (ST) in the following manner: the upper limb (not containing an indwelling arterial catheter) was raised slightly above the level of the heart and firm pressure was applied by the clinician’s index finger and thumb to the distal phalanx of the patient’s index finger for five seconds. The finger was then released and the time taken for the palmar pulp to return to its previous colour was recorded. Times were measured to the nearest second by a wristwatch (as is usual in clinical practice). Measurements were not made on overtly ischaemic limbs in patients with meningococcal disease. For postcardiac surgery patients, measurements were made after bypass rewarming was complete, defined as a rectal temperature of ≥ 37°C. All measurements were made in an open, well-lit intensive care unit, where the ambient temperature was maintained at 22°C. The median number of capillary refill time measurements for each patient was two. No patient had more than three measurements, and repeat measurements were only taken after a time interval of at least one hour and after a treatment that might alter the haemodynamic profile, such as a fluid bolus or the addition of an inotropic agent. Normal capillary refill was defined as < 2 seconds, and prolonged refill as > 2 seconds.

The following haemodynamic parameters were measured concurrently with capillary refill time, namely: cardiac index (CI), central venous pressure, systemic vascular resistance index (SVRI), stroke volume index (SVI), core–peripheral temperature gap, and whole blood lactate. Core temperature was measured rectally, and peripheral temperature taken on the distal aspect of a limb that was not overtly ischaemic (usually the great toe). Cardiac index was measured using femoral artery thermodilution (COLD Z-021, Pulsion Medical Systems, Munich, Germany) using a technique described previously; five consecutive measurements were made, then averaged. Whole blood lactate was measured using the YSI 2300 STAT plus analyser (Yellow Springs Instruments, Ohio, USA). Central venous pressure was measured from a catheter in the superior vena cava, confirmed on chest x-ray. Table 2 gives the formulae for haemodynamic variables.

Data were assumed to be non-parametric. Spearman’s correlation coefficients were calculated for continuous data. The Mann-Whitney test was used to assess differences between sample medians from groups with normal and prolonged capillary refill time. If a significant difference existed, a receiver operating characteristic (ROC) curve was constructed to quantify the value of capillary refill time that had the greatest predictive value. Bonferroni corrections for multiple comparisons were used, with a level of significance set at p < 0.01.

Because the study involved comparison of capillary refill time and measurements made as part of routine clinical practice (measurement of capillary refill time was only performed when it was deemed necessary to measure CI) institutional ethical approval was not sought.

Results

For cardiac patients, both capillary refill time and core–peripheral temperature gap correlated poorly with all haemodynamic variables (table 3). Not surprisingly, these two parameters were closely related (r = 0.58; 95% confidence interval (CI), 0.33 to 0.76; p < 0.0001).

Cardiac patients with normal and prolonged capillary refill time showed no difference with respect to median CI (3.42 v 2.93 l/min/m²; p = 0.57), SVI (28 v 24 ml/m²; p = 0.85), central venous pressure (8 v 9 mm Hg; p = 0.75), SVRI (1476 v 1474 dyne/s/cm²/m²; p = 0.42), or lactate (1.4 v 1.8 mmol/l; p = 0.50).

Among the non-cardiac patients, capillary refill time and core–peripheral temperature gap

Table 3  Correlation between capillary refill time (CRT), core–peripheral temperature gap, and haemodynamic variables for patients after cardiac surgery and general patients

<table>
<thead>
<tr>
<th>Patient group</th>
<th>Variable</th>
<th>CRT' (95% CI)</th>
<th>p value</th>
<th>Core-peripheral temperature gap (95% CI)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>After cardiac surgery</td>
<td>CI</td>
<td>−0.06 (−0.36 to 0.25)</td>
<td>0.70</td>
<td>−0.12 (−0.41 to 0.20)</td>
<td>0.44</td>
</tr>
<tr>
<td></td>
<td>CVP</td>
<td>−0.14 (−0.43 to 0.17)</td>
<td>0.35</td>
<td>−0.18 (−0.46 to 0.14)</td>
<td>0.26</td>
</tr>
<tr>
<td></td>
<td>SVRI</td>
<td>0.06 (−0.25 to 0.36)</td>
<td>0.68</td>
<td>0.14 (−0.17 to 0.43)</td>
<td>0.36</td>
</tr>
<tr>
<td></td>
<td>SVI</td>
<td>−0.09 (−0.39 to 0.22)</td>
<td>0.54</td>
<td>−0.19 (−0.47 to 0.12)</td>
<td>0.22</td>
</tr>
<tr>
<td></td>
<td>Lactate</td>
<td>0.11 (−0.22 to 0.42)</td>
<td>0.51</td>
<td>0.11 (−0.22 to 0.43)</td>
<td>0.50</td>
</tr>
<tr>
<td>General</td>
<td>CI</td>
<td>−0.21 (−0.47 to 0.08)</td>
<td>0.13</td>
<td>−0.24 (−0.52 to 0.08)</td>
<td>0.13</td>
</tr>
<tr>
<td></td>
<td>CVP</td>
<td>0.34 (0.04 to 0.58)</td>
<td>0.02</td>
<td>0.00 (−0.30 to 0.32)</td>
<td>0.99</td>
</tr>
<tr>
<td></td>
<td>SVRI</td>
<td>0.01 (−0.29 to 0.31)</td>
<td>0.05</td>
<td>0.29 (−0.04 to 0.55)</td>
<td>0.08</td>
</tr>
<tr>
<td></td>
<td>SVI</td>
<td>−0.46 (−0.67 to −0.18)</td>
<td>0.001</td>
<td>−0.29 (−0.56 to 0.03)</td>
<td>0.07</td>
</tr>
<tr>
<td></td>
<td>Lactate</td>
<td>0.47 (0.21 to 0.66)</td>
<td>&lt; 0.001</td>
<td>0.31 (−0.02 to 0.57)</td>
<td>0.06</td>
</tr>
</tbody>
</table>

CI, cardiac index; CVP, central venous pressure; SVRI, systemic vascular resistance index; SVI, stroke volume index.

CI, cardiac index; CVP, central venous pressure; SVRI, systemic vascular resistance index; SVI, stroke volume index.
Haemodynamic status in paediatric intensive care patients

Table 4  Haemodynamic parameters for general patients with normal and prolonged capillary refill times (CFT)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>CFT &lt; 2 seconds</th>
<th>CFT &gt; 2 seconds</th>
<th>p value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>CI (l/min/m²)</td>
<td>5.09 (4.49–5.76)</td>
<td>4.13 (3.58–4.89)</td>
<td>0.05</td>
</tr>
<tr>
<td>CVP (mm Hg)</td>
<td>11 (9–15)</td>
<td>15 (12–17)</td>
<td>0.05</td>
</tr>
<tr>
<td>SVRI (dyne/s/cm⁵/m²)</td>
<td>976 (817–1037)</td>
<td>956 (847–1191)</td>
<td>0.96</td>
</tr>
<tr>
<td>SVI (ml/m²)</td>
<td>38 (29–42)</td>
<td>28 (23–34)</td>
<td>0.01</td>
</tr>
<tr>
<td>Lactate (mmol/l)</td>
<td>1.1 (0.8–2.1)</td>
<td>1.7 (1.3–2.4)</td>
<td>0.15</td>
</tr>
</tbody>
</table>

*Mann-Whitney.

CI, cardiac index; CVP, central venous pressure; IQ, interquartile range; SVRI, systemic vascular resistance index; SVI, stroke volume index.

Figure 1  Receiver operating characteristic curve for general patients showing the predictive ability of capillary refill time for a low stroke volume index (< 30 ml/m²). Area under the curve, 0.80 (95% CI, 0.66 to 0.91).

Also exhibited a close association (r = 0.66; 95% CI 0.44 to 0.81; p < 0.0001). Overall capillary refill time exhibited a stronger correlation between haemodynamic variables, notably SVI and lactate (table 3). Table 4 shows the differences among non-cardiac patients with normal and prolonged capillary refill time.

Because SVI was the only parameter related consistently to capillary refill time, the predictive value of capillary refill time to pick up a low SVI (less than 30 ml/m²) was assessed by an ROC curve (fig 1). The best predictive ability was shown with a capillary refill time of ≥ 6 seconds, giving a sensitivity of 57%, specificity of 94%, positive predictive value of 80%, and negative predictive value of 83%. In contrast, a capillary refill time of ≥ 3 seconds gave a sensitivity of 86%, specificity of 47%, positive predictive value of 41%, and negative predictive value of 88%.

Discussion

To our knowledge, the earliest mention of capillary refill in medical literature was by Beecher in 1947, who proposed this measure as a means of grading shock. It was introduced into the assessment of trauma by Champion, with the anecdotal observation that two seconds should be regarded as the upper limit of normal. This figure was later validated in children, with significant variation being found in older age groups.

Capillary refill time has been of value in measuring the degree of dehydration in children with diarrhoea, as well as when used with other clinical parameters in assessing the adequacy of resuscitation after paediatric blunt trauma.

Several caveats apply when measuring capillary refill time: (1) the choice of limb is important because capillary refill time may be prolonged in the lower limbs compared with the upper limbs; (2) the limb should be raised above the level of the heart to avoid venous refill; (3) adequate lighting is essential; and (4) decreased ambient temperature might also prolong capillary refill time. The effect of fever on capillary refill time remains controversial; certainly this question has not been examined adequately among children and in clinical situations other than dehydration.

We attempted to standardise conditions under which capillary refill time was measured. All observations were made in the same manner by the same clinician using a wristwatch (as usual in everyday practice), and the ambient temperature was maintained above 22°C. However, it is worth noting that 13 of 90 measurements were made when patients’ core temperatures were greater than 38.5°C, and that most of the patients were on inotropic support, or receiving vasoactive drugs. Undoubtedly, this would affect capillary refill times in these patients, who are representative of the paediatric intensive care population at large.

Resuscitation skills taught on both the APLS and PALS courses place great emphasis on prolongation of capillary refill time as an indicator of shock, with treatment directed at volume replacement initially, followed by inotropic support. However, to our knowledge there has been no published data examining the usefulness of capillary refill time in the post-resuscitation phase, when the patient reaches the intensive care unit.

Among postcardiac surgical patients, we have shown that capillary refill time and core-peripheral temperature gap are related, a finding that has been demonstrated in adults. Previous work in children has shown temperature gap to be a poor indicator of global haemodynamic status after cardiac surgery; our findings concur and suggest that capillary refill time is an equally poor predictor.

However, capillary refill time did perform better than temperature gap among non-cardiac patients, who predominantly had septic shock. Prolongation of capillary refill time correlated with reduced SVI (which might suggest reduced contractility, assuming adequate volume replacement had been instituted), and inadequate blood flow as assessed by higher blood lactate concentrations. However, when analysed according to normal and prolonged capillary refill time around the traditional cutoff value of two seconds, these differences diminished (p = 0.01 and 0.15 for SVI and lactate, respectively). A possible explanation may be that a cut off of two seconds for capillary refill time is too conservative for an intensive care unit population, this is suggested further by ROC analysis highlighting a capillary refill time of ≥ 6 seconds as the best predictor for a reduced SVI.
There was a trend (p = 0.02) towards correlation of capillary refill time and central venous pressure in the non-cardiac group. Interestingly, this was in the opposite manner expected if a low central venous pressure is meant to correspond to hypovolaemia. Unfortunately, this is probably an oversimplification among critically ill, ventilated patients, where central venous pressure is affected by factors other than volume status alone, namely myocardial contractility and compliance, heart rate, and transpulmonary pressure.25

It is not our wish to devalue the role of capillary refill time when used in conjunction with other clinical signs in the acute resuscitation scenario. However, its role in the intensive care unit, where more objective measures of haemodynamic status are available, is questionable. Capillary refill time bears no relation to commonly measured haemodynamic variables in the period after cardiac surgery, and for other critically ill children the presence of a mildly prolonged capillary refill time should be interpreted with caution.

9 Beecher HK, Simeone FA, Burnett CH. The internal state of the severely wounded man on entry to the most forward hospital. *Surgery* 1947;22:672–81.
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