Capillary Refill Time: Is It Still a Useful Clinical Sign?

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Capillary refill time (CRT) is widely used by health care workers as part of the rapid, structured cardiopulmonary assessment of critically ill patients. Measurement involves the visual inspection of blood returning to distal capillaries after they have been emptied by pressure. It is hypothesized that CRT is a simple measure of alterations in peripheral perfusion. Evidence for the use of CRT in anesthesia is lacking and further research is required, but understanding may be gained from evidence in other fields. In this report, we examine this evidence and factors affecting CRT measurement. Novel approaches to the assessment of CRT are under investigation. In the future, CRT measurement may be achieved using new technologies such as digital videography or modified oxygen saturation probes; these new methods would remove the limitations associated with clinical CRT measurement and may even be able to provide an automated CRT measurement. (Anesth Analg 2011;113: 120–3)

Capillary refill time (CRT) is defined as the time taken for a distal capillary bed to regain its color after pressure has been applied to cause blanching. It was first introduced by Beecher et al.[1] in 1947 using the categories normal, definite slowing, and very sluggish. These were correlated with the presence and severity of shock. In 1980, Champion included CRT measurement in his trauma score[2] and it was subsequently endorsed by the American College of Surgeons. CRT has become widely used in adults and children and has been incorporated into advanced life support guidelines as part of the rapid, structured cardiopulmonary assessment of critically ill patients.[3]

The upper limit of normal for CRT was defined as 2 seconds, based on the observations of a member of the clinical staff working with Dr. Champion.[4] Over the past 30 years, this definition, the factors affecting CRT, and the validity of CRT measurements have been debated in the literature.

Measurement of CRT involves the visual inspection of blood returning to distal capillaries after they have been emptied by pressure application. The physiological principles of peripheral perfusion are complex. How well a distal capillary bed is perfused depends on a number of factors; the main determinants are capillary blood flow (a product of the driving pressure, arteriolar tone, and hemorheology) and capillary patency (reflected by the functional capillary density, the number of capillaries in a given area that are filled with flowing red blood cells). Arteriolar tone depends on a fine balance between vasoconstrictive (norepinephrine, angiotensin II, vasopressin, endothelin I, and thromboxane A_2) and vasodilatory (prostacyclin, nitric oxide, and products of local metabolism such as adenosine) influences, which together regulate capillary perfusion depending on the metabolic requirements of the tissue cells.[5] It is hypothesized that alterations in distal capillary bed perfusion will affect the measurement of CRT by altering the time for the distal capillaries to become refilled with blood. It is important to note that there are no current publications directly supporting this theory.

In this article, we focus on the potential use of CRT measurement in anesthesia although evidence for this specifically is lacking. A number of published studies have determined the factors that affect CRT measurement and these are summarized. Furthermore, we examine some of the methods for automated measurement of CRT.

FACTORS AFFECTING CRT MEASUREMENT

The nature of the clinical CRT measurement makes it susceptible to errors. Various factors may have a significant impact on the results obtained and are rarely considered by health care workers.[6]

Age

Age affects CRT measurement. The upper limit of normal for CRT in neonates was found to be 3 seconds irrespective of sex, gestation, weight, size for gestational age, nursery containers, or phototherapy.[7] In children, an upper limit of normal of 2 seconds has been reported.[8–10] Studies in adults have found a wider variation,[11] with an average increase of 3.3% per decade of age.[12] One study found a median CRT for the pediatric population (up to 12 years old) of 0.8 second; for adult men, 1.0 second; adult women, 1.2 seconds; and in those older than 62 years, 1.5 seconds.[9] This study concluded that if 95% of all normal patients are to be contained within the normal range then the upper limit of normal for adult women should be increased to 2.9 seconds and for the elderly to 4.5 seconds.

Temperature

Ambient, skin, and core temperature affect CRT measurement. The CRT of healthy children in a warm environment (mean 25.7°C) was <2 seconds but only 31% had a similar measurement in a cold environment (mean 19.4°C).[10] The

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CRT in newborns is shorter in those nursed in incubators or under radiant heaters.[7] Similar findings have been seen in adults; CRT decreased by 1.2% per degree Celsius increase in ambient temperature.[12] Local skin temperature affects CRT in both adults and children. In adults, the immersion of a hand into cold water at 14°C prolonged CRT.[9] Fingertip skin temperature varied with the ambient temperature and each 1°C reduction in skin temperature was accompanied by a 0.21 second increase in CRT.[10] Furthermore, a statistically significant relationship was found between CRT and core temperature; CRT was on average 5% shorter for each 1°C increase in tympanic temperature.[12] These relationships also exist for newborns whose CRT decreased as ambient, skin, and axillary temperature increased.[13]

Ambient Light

Poor light conditions make it difficult to assess CRT. In daylight conditions (partly cloudy day, approximately 4000 lux), CRT was reported as normal in 94.2% of healthy participants compared with only 31.7% of the same participants in dark conditions (moonlight or street lamp, approximately 3 lux).[14]

Pressure Application

There is no universal agreement on the optimal duration and amount of pressure or site used when assessing CRT. Applying moderate pressure for 3 seconds,[15] 5 seconds,[9,10,13,14] or until the capillary bed blanches[16] has been suggested. Pressure applied for <3 seconds gives a shorter CRT; no difference was found with pressure applied for 3 to 7 seconds.[17] Application of light pressure (the minimal pressure to cause blanching) resulted in shorter CRT than moderate pressure and with less variability.[8] CRT measurement at different sites of the body will produce different results. CRT measurements in newborns from the midpoint of the forehead and chest are more consistent than measurements from the heel or palm.[7] CRT measured at the heel can be significantly longer than in the finger.[8,10] In newborns, especially premature babies, testing the pulp of the finger is more difficult compared with using the forehead or chest where movement is less likely to interfere with the testing. The World Health Organization advocates using the nail of the thumb or big toe[15]; other studies suggest using the soft tissue at the kneecap or forearm level.[18] A survey of pediatric health care workers found that approximately two-thirds perform CRT on the chest with only one-third using the pulp of the distal phalanx of the finger.[6] This finding is at odds with studies, which mainly use the distal phalanx.[8,10,12,19]

Intra- and Interobserver Reliability

Poor interobserver reliability is a major limitation to the use of the test. The interobserver reliability of CRT measurement (using a standardized method to assess the CRT, without a timing device, to a resolution of half a second) on clinically stable adult patients in the emergency department showed a mean difference in CRT measurements among clinicians of 0 seconds; however, the 95% limits of agreement were −1.7 to +1.9 seconds. More importantly, in only 70% of subjects being studied was there agreement as to CRT being normal or abnormal (using a 2-second upper limit of normal).[20] In another study, 5 experienced physicians measured the CRT on each of 5 patients' halluces.[11] Evaluating intraobserver reliability, they found an overall intraclass coefficient (ICC) of 0.72; however, the overall standard error of the measurement was ±1.94 seconds. The ICC for interobserver reliability was worse. Two studies standardized the method of measuring CRT and used a stopwatch to measure time. The first found that the ICC for interobserver reliability was 0.7, and for intraobserver reliability, 0.96.[10] The second, a study of neonates, found that the correlation coefficient for CRT measurement on the foot among 3 observers ranged from 0.47 to 0.68 and for the hand, 0.55 to 0.71.[13] The latter 2 results might not be representative of usual clinical practice given the strict method applied for assessment of CRT. A study of children admitted to a district hospital in Kenya evaluated 4 clinicians' assessments of CRT on 100 patients. A low-moderate agreement was found ($\kappa = 0.42$); however, better agreement was found for CRT <1 second and >4 seconds.[21]

In addition to the variations that can occur because of differences in amount and duration of pressure applied to the finger, the clinician must also decide on the end point of capillary refilling. Initial rapid partial refilling of the capillaries may be followed by a slower complete filling. Defining the end point is subjective and introduces further error in the assessment of CRT.

THE CLINICAL APPLICATION OF CRT MEASUREMENT

As mentioned above, there are no publications relating specifically to the use of CRT measurement in anesthesia. Its potential use in this field must be inferred from the currently available evidence.

Pediatrics

There is a good correlation between CRT measurement and degree of dehydration in children admitted to the hospital with diarrhea. A CRT of 1.5 to 3 seconds is associated with a fluid deficit of 50 to 100 mL/kg (measured as difference in weight from time of admission to that after rehydration in infants with diarrhea) and a CRT of >3 seconds suggests a deficit of >100 mL/kg.[8] A prolonged CRT was a major predictor of children who proved to have >5% dehydration as judged by subsequent weight recovery in the hospital.[22] Children with dehydration (≥5% body weight deficit) had a statistically significant longer mean CRT (2.0 ± 1.0 seconds vs 1.3 ± 0.5 seconds) compared with well-hydrated children. The presence of fever in these children did not have a clinically important effect on the estimate of CRT.[23] A more recent review investigating clinical measurements to assess dehydration in children found that CRT was the best individual sign for diagnosing children with 5% dehydration.[16]

In children with septic shock in the pediatric intensive care unit, CRT was compared with hemodynamic variables. The best correlation was between CRT and stroke volume index ($r = -0.46$; 95% confidence interval, −0.67 to 0.18) and lactate (0.47; 0.21 to 0.66), but this was still modest. CRT showed best predictive ability to identify a low stroke volume index when it was ≥6 seconds.[19] Of note, most patients were receiving inotropic support for

their arterial blood pressure, which would have affected CRT but is representative of the pediatric intensive care unit population. No correlation between CRT and other hemodynamic variables was found in children after cardiac surgery.[19]

Prolonged CRT was found to be independently associated with death in children with severe and complicated malaria in Sub-Saharan Africa (a disease that results in 2 million deaths annually). For children with severe anemia associated with malaria, the risk of dying was 2-fold higher if they had a prolonged CRT.[24] Prolonged CRT (>3 seconds) is also a component of a prognostic scoring scale developed for African meningococcal epidemics.[25]

A delayed CRT was identified as one of the strongest warnings for serious infection in developed countries in a recent high-profile review of clinical features used to confirm or exclude the possibility of serious infection in children presenting to ambulatory care settings.[26] This accords with results published by the World Health Organization for resource-poor countries.[27]

Adults

The presence of a CRT of >2 seconds is, however, not predictive of mild-to-moderate hypovolemia in adults. The CRT was inconsistent when measured before and after rehydration in 32 adult emergency patients with a history suggestive of hypovolemia and hypotension or abnormal orthostatic signs (increase in heart rate of ≥20 beats per minute, or diastolic blood pressure decrease by >15 mm Hg when the patient changed from a supine to standing position), and in 47 blood donors before and after a 450-mL blood donation. Using the 2-second upper limit of normal gave a sensitivity of 11% for the blood donors, 47% for patients with abnormal orthostatic signs, and 77% for those with hypotension.[28] CRT measurement with subjective assessment of peripheral perfusion, in resuscitated critically ill adult patients assessed in the first 24 hours of admission and once they were hemodynamically stable, was able to identify those with a more severe organ dysfunction and higher lactate levels.[29]

From the available evidence, it seems that CRT measurement is most useful in the assessment of patients with shock states. In these situations, there may be an alteration in the balance of vasoconstrictor and vasodilator substances and in the cross-talk between endothelial cells so that regulation of the microvascular blood flow is impaired. Abnormalities also include arteriovenous shunting, "stop-flow" capillaries (flow is intermittent), "no-flow" capillaries (capillaries are obstructed), failure of capillary recruitment, and increased capillary permeability with interstitial edema. Capillaries may become obstructed because of swollen endothelial cells, reduced deformability of circulating erythrocytes, leukocyte-platelet-fibrin thrombi, or compression by edema fluid, the end result being a reduction in the functional capillary density. This suggests that CRT may indeed be measuring alterations in perfusion of the distal capillary bed. The link between systemic hemodynamics and this peripheral perfusion is relatively loose, so that these alterations can be observed even when systemic hemodynamics are within satisfactory goals. However, if cardiac output and arterial pressure are critically altered, then they can affect peripheral perfusion.[30] If CRT is indeed a simple measure of the state of distal capillary bed perfusion, then it is not surprising that Tibby et al.[19] did not find an important correlation between systemic hemodynamic variables and CRT measurement. The findings from other studies that CRT is a good predictor of significant dehydration, serious infection, severe organ dysfunction, and higher lactate levels relate to CRT as a measure of distal perfusion as a whole rather than being equivalent to any one single hemodynamic variable.

This evidence may be extrapolated to the use of CRT during the preoperative assessment of patients and in patients undergoing general anesthesia, particularly emergency procedures and those involving significant blood loss and large fluid shifts.

Attention has focused more recently on automated methods of measuring CRT. These include digital videography (digitally measured capillary-refill time [DCRT])[31] and the use of a photoplethysmographic (PPG) sensor based on a blue-light emitter.[32]

DCRT replaces visual observation by substituting an electronic image sensor array for the human eye. In a study of 83 children with acute gastroenteritis who were assessed by clinicians to have at least mild dehydration, DCRT was found to be more accurate at determining the presence of significant dehydration (≥5%) than overall clinical assessment. The range of DCRT measurements in well-hydrated children (0.2–0.4 seconds) was substantially less than that of the standard CRT measurement.

The low wavelength light of the blue-light PPG sensor only penetrates as far as the upper skin capillaries. To detect the occlusion of skin capillaries and track the refill process, pressure was applied to the probe until the signal from the PPG sensor disappeared with subsequent release after 4 to 5 seconds. Three variables have been suggested for estimating refill time: time for the signal to reach the original baseline level after pressure release; time for the signal to reach its maximum; and time for the signal to return from maximum to its initial level.

Methods other than CRT are being used to digitally assess peripheral perfusion. Body temperature gradient measurements, orthogonal polarization spectral imaging, peripheral perfusion index derivation from pulse oximetry, near-infrared spectroscopy, and laser Doppler flowmetry are examples of semiautomated methods. Each of these methods offers advantages and limitations that have been previously discussed.[33]

Digitalized techniques for measuring CRT are not available to the practicing clinician, and current designs requiring a computer for processing results, specially rebuilt pulse oximeter probes, or a video camera render them impractical for routine use in the clinical setting. Before automatically measured CRT can replace the standard manual test, the techniques must be validated in a broad range of subjects, including studies to evaluate their robustness in different lighting and temperature conditions. Digitalized CRT measurement offers new techniques for the quantification of CRT and the opportunity to define a new "gold standard" for noninvasive CRT measurement. For example, a temperature sensor measuring ambient or skin

temperature[34] could be embedded with the sensor measuring the CRT to provide a temperature-corrected value, and a sensor used to measure CRT could be used in combination with other clinical variables such as heart rate, pulse oximeter saturation, and respiratory rate to produce a diagnostic tool for clinical triage.

In summary, CRT measurement is affected by multiple external factors but has predictive value in the assessment of dehydration and serious infection in children. There are few outcomes data to support its use in adults. In an intensive care unit with good light and in a warm room, a CRT of <2 seconds might be reassuring but, as with all tests, clinical decisions should not be based on CRT measurement in isolation but rather as one aspect of the clinical picture as a whole. There is no evidence to justify its use in anesthetized patients. Operating rooms are cold, patients are often draped, which limits access, and because most anesthetics are potent vasodilators, the use of CRT to guide practice is not justified. The possibility of a false-positive or false-negative assessment is simply too great. Digitalized and perhaps automated CRT measurements have the potential to overcome some of these limitations. The use of innovative technology in the assessment of CRT would be an opportunity to apply more robust and reliable noninvasive methods to assess the peripheral circulation.

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REFERENCES

1. Beecher HK, Simeone FA, Burnett CH, Shapiro SL, Sullivan ER, Mallory TB. The internal state of the severely wounded man on entry to the most forward hospital. Surgery 1947;22:672–711
2. Champion HR, Sacco WJ, Carnazzo AJ, Copes W, Fouty WJ. Trauma score. Crit Care Med 1981;9:672–6
3. Hazinski MF, Zaritsky AL, Nadkarni VM, eds. PALS Provider Manual. Dallas: American Heart Association, 2002
4. Baraff LJ. Capillary refill: is it a useful clinical sign? Pediatrics 1993;92:723–4
5. Harrison TR, ed. Harrison's Principles of Internal Medicine. 14th ed. New York: McGraw-Hill, 1998
6. Lobos AT, Menon K. A multidisciplinary survey on capillary refill time: inconsistent performance and interpretation of a common clinical test. Pediatr Crit Care Med 2008;9:386–91
7. Strozik KS, Pieper CH, Roller J. Capillary refilling time in newborn babies: normal values. Arch Dis Child Fetal Neonatal Ed 1997;76:F193–6
8. Saavedra JM, Harris GD, Li S, Finberg L. Capillary refilling (skin turgor) in the assessment of dehydration. Am J Dis Child 1991;145:296–8
9. Schriger DL, Baraff L. Defining normal capillary refill: variation with age, sex, and temperature. Ann Emerg Med 1988;17:932–5
10. Gorelick MH, Shaw KN, Baker MD. Effect of ambient temperature on capillary refill in healthy children. Pediatrics 1993;92:699–702
11. Klupp N, Keenan A. An evaluation of the reliability and validity of capillary refill time test. Foot 2007;17:15–20
12. Anderson B, Kelly AM, Kerr D, Clooney M, Jolley D. Impact of patient and environmental factors on capillary refill time in adults. Am J Emerg Med 2008;26:62–5
13. Raju NV, Maisels MJ, Kring E, Schwarz-Warner L. Capillary refill time in the hands and feet of normal newborn infants. Clin Pediatr (Phila) 1999;38:139–44
14. Brown LH, Prasad NH, Whitley TW. Adverse lighting condition effects on the assessment of capillary refill. Am J Emerg Med 1994;12:46–7
15. World Health Organization. Emergency triage assessment and treatment. In: World Health Organization. Management of the Child with a Serious Infection or Severe Malnutrition: Guidelines for the Care at the First Referral Level in Developing Countries. Geneva: World Health Organization, 2000:1–14
16. Steiner MJ, DeWalt DA, Byerley JS. Is this child dehydrated? JAMA 2004;291:2746–54
17. Strozik KS, Pieper CH, Cools F. Capillary refilling time in newborns: optimal pressing time, sites of testing and normal values. Acta Paediatr 1998;87:310–2
18. Beckow J. The truth about capillary refill. JEMS 2005;30:14
19. Tibby SM, Hatherill M, Murdoch IA. Capillary refill and core-peripheral temperature gap as indicators of haemodynamic status in paediatric intensive care patients. Arch Dis Child 1999;80:163–6
20. Anderson B, Kelly AM, Kerr D, Jolley D. Capillary refill time in adults has poor inter-observer agreement. Hong Kong J Emerg Med 2008;15:71–4
21. Otieno H, Were E, Ahmed I, Charo E, Brent A, Maitland K. Are bedside features of shock reproducible between different observers? Arch Dis Child 2004;89:977–9
22. Mackenzie A, Barnes G, Shann F. Clinical signs of dehydration in children. Lancet 1989;2:605–7
23. Gorelick MH, Shaw KN, Murphy KO, Baker MD. Effect of fever on capillary refill time. Pediatr Emerg Care 1997;13:305–7
24. Evans JA, May J, Ansong D, Antwi S, Asafo-Adjei E, Nguah SB, Osei-Kwakye K, Akoto AO, Ofori AO, Sambian D, Sylverken J, Busch W, Timmann C, Agbenyega T, Horstmann RD. Capillary refill time as an independent prognostic indicator in severe and complicated malaria. J Pediatr 2006;149:676–81
25. Ajayi-Obe EK. Prognostic scores for use in African meningococcal epidemics. Bull World Health Organ 1996;76:149–52
26. Van den Bruel A, Haj-Hassan T, Thompson M, Buntinx F, Mant D. Diagnostic value of clinical features at presentation to identify serious infection in children in developed countries: a systematic review. Lancet 2010;375:834–45
27. Clinical signs that predict severe illness in children under age 2 months: a multicentre study. Lancet 2008;371:135–42
28. Schriger DL, Baraff LJ. Capillary refill: is it a useful predictor of hypovolemic states? Ann Emerg Med 1991;20:601–5
29. Lima A, Jansen TC, van Bommel J, Ince C, Bakker J. The prognostic value of the subjective assessment of peripheral perfusion in critically ill patients. Crit Care Med 2009;37:934–8
30. De Backer D, Ortiz JA, Salgado D. Coupling microcirculation to systemic hemodynamics. Curr Opin Crit Care 2010;16:250–4
31. Shavit I, Brant R, Nijssen-Jordan C, Galbraith R, Johnson DW. A novel imaging technique to measure capillary-refill time: improving diagnostic accuracy for dehydration in young children with gastroenteritis. Pediatrics 2006;118:2402–8
32. Kviesis-Kipge E, Curkste E, Spigulis J, Gardovska D. Optical Studies of the Capillary Refill Kinetics in Fingertips. In: Doessel O, Schlegel WC, eds. World Congress on Medical Physics and Biomedical Engineering, 2009, Munich, Germany. Berlin: Springer, 2009:377–9
33. Lima A, Bakker J. Noninvasive monitoring of peripheral perfusion. Intensive Care Med 2005;31:1316–26
34. Messerges J, Hutchinson G, inventors. Method and apparatus for measuring capillary refill time and carrying out pulse oximetry with a single device. United States patent US 20070282182, 2006