JOURNAL OF INTERNATIONAL CRISIS AND RISK COMMUNICATION RESEARCH
ISSN: 2576-0017
2024, VOL 7, NO S10

Capillary Refill Time: A Vital Sign for Nurses in Sepsis Management

Ibrahim Dablan Fahad Aljaloud [1], Aqeel Mohammad Aqeel Altamimi [2], Mashael Basheer Radhi Alshammari [3], Wafa Mohammad Awadh Alanzi [4], Saud Mohammad Awadh Alenezi [5], Khaled Saeed Al Massad [6], Sarah Turqei Saeed Alsubaei [7], Galmiah Hamzah Al kiady [8], Mohammed Mofarreh Asiri [9], Falah Ayedh Ali Al- Qahtani [10], Naif Faraj Almutiri [11], Hassan Essa Ammari [12], Hamad Mahdi Ali Al Zaman [13], Taghreed Yahya Moh'd ALwadey [14], Moneerah Hassan Hamed Hotan [15].

[1]Nursing Eradah Complex for Mental Health, Ministry of Health, Kingdom of Saudi Arabia. ialjaloud@moh.gov.sa
[2]Nursing specialist, Eradah Complex for Mental Health, Ministry of Health, Kingdom of Saudi Arabia. aqaltamimi@moh.gov.sa
[3]Nursing, Ministry of Health branch in Hail Region, Ministry of Health, Kingdom of Saudi Arabia. M.al.ghreeb.7@gmail.com
[4]Nursing, Hail Health Cluster, Ministry of Health, Kingdom of Saudi Arabia. wm.alafri@gmail.com
[5]Nursing, Aja long-term care hospital and medical in Ha'il, Ministry of Health, Kingdom of Saudi Arabia. Samoalonazi@moh.gov.sa
[6]Nursing, King Khalid Hospital in Al Kharj, Ministry of Health, Kingdom of Saudi Arabia. khaled.waleed94@gmail.com
[7]Nursing Specialist, King Abdulaziz Specialist Hospital, Ministry of Health, Kingdom of Saudi Arabia. Salsubaei@moh.gov.sa
[8]Nurse, Aradah Complex and Mental Health, Ministry of Health, Kingdom of Saudi Arabia. galkyady@moh.gov.sa
[9]Nurse Technician, Aser Central Hospital, Ministry of Health, Kingdom of Saudi Arabia. abumela1138@gmail.com
[10]Nursing Technician, Prince Sultan Military Medical City. Fla73ayedh@hotmail.com
[11]Technician Nursing, Branch of the Minstry of Health in Riyadh, Region, Ministry of health Kingdom of Saudi Arabia. nafalmutairi@moh.gov.sa
[12]Nursing, Ministry of health Kingdom of Saudi Arabia. ammari.h2014@gmail.com
[13]Nursing specialist, King Khaled Hospital in Najran, Ministry of health Kingdom of Saudi Arabia.
[14]Midwife, King Faisal Medical complex-Taif, Ministry of health Kingdom of Saudi Arabia. talwadey@moh.gov.sa
[15]Nurse, jizan General Hospital, Ministry of health Kingdom of Saudi Arabia. aaa045534@gmail.com

ABSTRACT

Capillary refill time (CRT) is a non-invasive marker of peripheral perfusion that plays a crucial role in the management of critically ill patients, particularly those with sepsis. This narrative review, adhering to PRISMA guidelines, investigates the reliability and clinical significance of CRT in sepsis care. CRT assessments are influenced by factors such as age, sex, temperature, lighting, and measurement

techniques. Inconsistencies in CRT implementation and interpretation among healthcare professionals highlight the need for standardized protocols and comprehensive training to minimize variability and enhance reliability. While there is no universally accepted cutoff value for normal CRT, studies suggest that CRT > 2.5-3 seconds indicates impaired tissue perfusion and is associated with adverse outcomes in sepsis patients. CRT serves as a warning sign for severe infections, a triage tool for identifying patients at risk, and a marker of tissue hypoperfusion. It correlates with microcirculatory parameters and lactate levels, reflecting the presence and severity of shock. CRT-guided fluid resuscitation strategies have shown promise in reducing organ dysfunction and mortality compared to lactate-targeted approaches. Persistent abnormal CRT post-resuscitation signifies a severe clinical phenotype with greater organ dysfunction and lower survival rates. To optimize the clinical application of CRT, healthcare providers should use standardized measurement techniques in appropriate patient populations while considering ambient factors. As a qualitative and quantitative measure, CRT serves as a critical tool for early detection of tissue hypoperfusion, guiding resuscitation efforts, and predicting outcomes in sepsis management.

Keywords: nurses, capillary refill time, CPT

Introduction

Tissue hypoxia and microcirculatory dysfunction are prevalent among critically ill patients (Kara et al., 2016). Approximately 17–21% of patients in Intensive Care Units (ICUs) exhibit microcirculatory abnormalities (Huang et al., 2023; Scorcella et al., 2018; Vellinga et al., 2015). Furthermore, individuals with clinical signs of impaired organ perfusion demonstrate an alarming 66% likelihood of microcirculatory disorders (Pranskunas et al., 2013). Septic shock is a predominant cause of shock in the ICU and is associated with significant morbidity and mortality (Vincent and De Backer, 2013). The pathogenesis of organ failure in sepsis is closely linked to microcirculatory dysfunction and endothelial impairment. Contemporary guidelines for sepsis management stress the importance of early recognition, fluid resuscitation, and prompt empirical antimicrobial therapy (Cusack et al., 2022; Evans et al., 2021). Consequently, assessing perfusion and microcirculatory disturbances is pivotal in the clinical care of patients with sepsis.

The skin, being the most accessible organ, serves as a practical site for evaluating perfusion status (Hariri et al., 2019). In circulatory failure, decreased systemic oxygenation and the redistribution of blood flow result in reduced organ perfusion. The cutaneous circulation's autoregulatory capacity diminishes, and sympathetic neurohumoral responses dominate, leading to reduced cutaneous perfusion. Clinically, poor peripheral perfusion manifests as pale, cold, mottled skin, and prolonged capillary refill time (CRT). CRT is considered a non-invasive marker of peripheral perfusion (Lima and Bakker, 2005).

Recent studies indicate that CRT is a valuable tool for guiding fluid therapy and predicting patient prognosis. However, CRT assessment is often performed inconsistently, and its interpretation varies among healthcare providers (Jacquet-Lagreze et al., 2022; Lobos and Menon, 2008). Discrepancies persist regarding the threshold for normal CRT values, hindering its widespread application and

undermining its reliability. To address these issues and enhance healthcare providers' awareness of CRT, this review consolidates information on CRT and investigates its reliability and clinical significance in sepsis management.

Although this is a narrative review, it adheres to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines to refine the paper screening strategy (Supplementary file 1). Relevant studies were identified through MEDLINE, EMBASE, and Google Scholar database searches. This review highlights factors influencing CRT, advocates for standardized measurement techniques with high interobserver reliability, and explores CRT's role in sepsis care (Fig. 1).

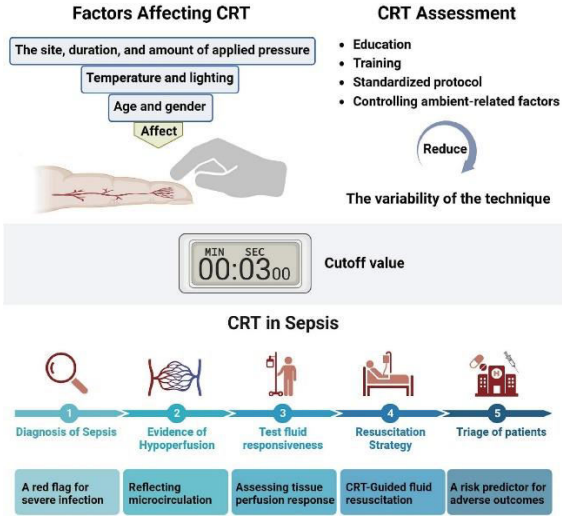

Fig. 1. Graphical abstract

What is Capillary Refill Time

Capillaries play a critical role in delivering essential components (e.g., nutrients, water, gases) and non-essential components (e.g., immune factors, temperature regulation) to tissues (Guven et al., 2020). Capillary refill time refers to the duration required for the skin to return to its baseline color after pressure is applied to a distal capillary bed, typically the fingertip (Ait-Oufella and Bakker, 2016). CRT was first described by Guedel in 1940 as a measure of circulatory efficiency and a correlate of shock severity (Guedel, 1940). In 1980, CRT became part of the Champion trauma score (Champion et al., 1981) and was later endorsed by the American College of Surgeons. As a component of the structured and rapid cardiopulmonary assessment of critically ill patients (Huber et al., 2019; Lima and Bakker, 2005), CRT has been integrated into life support and sepsis fluid resuscitation guidelines (Evans et al., 2021).

What Factors Affect Capillary Refill Time

CRT assessments are influenced by various factors, including age, sex, temperature, light, and the amount, duration, and location of applied pressure (Table 1) (Lamprea

et al., 2022; Lima and Bakker, 2005; Pickard et al., 2011; Schriger and Baraff, 1988).

Age and Sex

CRT values differ according to age and sex. In a healthy population, the median CRT is 0.8 seconds in children under 12 years, 1.0 second in adult males, 1.2 seconds in adult females, and 1.5 seconds in older adults aged 62 years and above (Schriger and Baraff, 1988). CRT increases by 3.3% for every decade of age, and the mean CRT is 7% lower in men compared to women (Anderson et al., 2008).

Temperature

Ambient, skin, and core temperatures significantly influence CRT measurements. CRT increases by 1.2% for every 1°C decrease in ambient temperature (Anderson et al., 2008). Low ambient temperatures notably prolong CRT at peripheral sites due to significant decreases in finger temperature, though this effect is less pronounced at the forehead and sternum (John et al., 2018). Skin temperature also impacts CRT; for example, immersing hands in 14°C water prolongs CRT in adults (Schriger and Baraff, 1988). A 1°C decrease in fingertip temperature results in a 0.21-second increase in CRT (Gorelick et al., 1993). Additionally, a statistically significant relationship exists between CRT and core temperature: CRT decreases by an average of 5% for each 1°C increase in core temperature (Anderson et al., 2008). Despite their statistical significance, factors such as age, sex, ambient temperature, and body temperature collectively account for only a minor fraction (8%) of CRT variability (Anderson et al., 2008).

Lighting

Lighting conditions affect the accuracy of CRT detection. Variability in CRT measurements due to environmental lighting can be as high as 1.94 seconds (Huber et al., 2019). Brown et al. demonstrated that under optimal lighting conditions, 94.2% of participants were identified as having normal CRT, whereas only 31.7% were classified as normal under dim lighting conditions (Brown et al., 1994).

Different CRT Measurement Methods

There remains no consensus regarding the optimal duration, amount, or site of pressure application during CRT assessments. Reported compression durations range from 3 to 15 seconds. Strozik et al. (1998) found that applying pressure for less than 3 seconds leads to shorter CRT values, whereas applying pressure for 3 to 7 seconds results in no significant difference in CRT. Alsma et al. (2017) noted that a compression duration of 15 seconds, compared to 5 seconds, prolongs CRT. Moderate pressure application or pressing until the capillary bed blanches (skin bleaching) has been documented (Pickard et al., 2011). Kawaguchi et al. (2019) examined CRT in healthy adults under compression pressures ranging from 1 to 7 Newtons and durations from 1 to 6 seconds. The study highlighted that the amount of pressure, rather than the duration, significantly affects CRT, with an optimal pressing strength of 3–7 Newtons for CRT measurement.

The site of CRT assessment includes various locations such as the forehead, earlobe (La Via et al., 2023), sternal region, forearm soft tissue, fingers, knees, and toes, with different sites yielding significantly varied CRT values (Fleming et al., 2016). In a survey of pediatric healthcare workers, about two-thirds evaluated CRT at the sternal region, while one-third assessed CRT at the fingertips (Lobos and Menon, 2008). Most adult studies, however, focus on fingertip CRT (Hernandez et al., 2019; Merdji et al., 2022), and the World Health Organization advocates both fingertip and toe CRT (Pickard et al., 2011). Ait-Oufella et al. (2014) found high reproducibility and excellent inter-rater agreement for index CRT and knee CRT in septic shock patients. Conversely, the lack of a standardized approach to using a chronometer during CRT measurement in both clinical research and practice may impact the precision and reliability of the results (Jacquet-Lagreze et al., 2022).

Lack of Consistency in CRT Implementation and Interpretation

A multidisciplinary survey highlighted inconsistencies in how CRT is performed and interpreted by healthcare professionals (Lobos and Menon, 2008). Healthcare providers with varying levels of training and expertise exhibited low interobserver agreement for CRT measurements (Toll John et al., 2019). A nationwide study reported moderate interobserver agreement among untrained physicians, with better concordance for index CRT (κ value: 0.40) compared to sternal CRT (κ value: 0.30) (Alsma et al., 2017). Similarly, untrained nurses who observed video recordings of index CRT achieved an interclass correlation of 0.62 (95% CI: 0.32–0.92) and a κ value of 0.58 (Brabrand et al., 2011). The underutilization and inconsistent application of CRT in clinical practice can lead to misconceptions about its reliability and clinical importance.

What is a CRT Standardization Protocol?

Training, education, and adherence to standardized protocols can reduce variability in CRT assessments caused by differences in implementation techniques and observation methods (Hernandez et al., 2019). Additionally, personal work experience influences the accuracy of CRT evaluations, with the level of training being a crucial determinant of reliability (Shinozaki et al., 2019b). Ultimately, variability in technique can be minimized through comprehensive training, the establishment of standardized protocols, and controlling for ambient factors (Shinozaki et al., 2021).

Van Genderen et al. (2014) reported good inter-rater reliability when trained researchers performed CRT assessments after abdominal surgery in adults, with Cohen's κ value of 0.91 (95% CI: 0.80–0.97). Ait-Oufella et al. (2014) standardized CRT assessment in septic shock patients, demonstrating high reproducibility with an 80% (73–86) inter-rater concordance for index CRT and 95% (93–98) for knee CRT. Using the same standardized protocol, Raia et al. (2022) evaluated repeated index CRT measurements in 40 critically ill patients, achieving excellent reproducibility with an intra-class correlation coefficient of 99.5% (95% CI: 99.3–99.8).

A standardized CRT assessment method involves applying pressure to the ventral surface of the patient’s right index finger using a glass slide, such as a microscope slide. Pressure is increased until the skin blanches, held for 10 seconds, and the time for the skin to return to its original color is recorded using a chronometer.

Jacquet-Lagrèze et al. (2019) recommended recording the entire procedure on video and calculating CRT as the average of two consecutive measurements. This approach enhances reproducibility and minimizes variability.

Innovations such as portable CRT measurement devices (Shinozaki et al., 2019c) can improve accuracy by reducing intra-operator variability. Advanced devices have been developed to enhance the repeatability and precision of CRT assessments (Gillespie et al., 2022; Jacquet-Lagreze et al., 2023).

The Common Cutoff Value of CRT

There is no universally accepted cutoff value for normal CRT. Schriger et al. (1988) suggested CRT < 2 seconds as normal for children and adult males, while cutoff values for females and older adults were 2.9 seconds and 4.5 seconds, respectively. However, this study did not involve critically ill patients in shock and primarily compared CRT before and after cold-water immersion. Consequently, its criteria are inadequate for detecting mild to moderate hypovolemia in adults (Schriger and Baraff, 1991).

Lavillegrand et al. (2022) identified CRT > 2 seconds as indicative of impaired tissue perfusion in septic shock patients. Ait-Oufella et al. (2014) demonstrated that a CRT cutoff of 2.4 seconds strongly predicted 14-day mortality in sepsis patients, leading subsequent studies to consider CRT > 2.5 seconds as abnormal peripheral perfusion in sepsis (Raia et al., 2022). In contrast, Morocho et al. (2022) reported an area under the receiver operating characteristic curve (AUC) of 0.819 (95% CI: 0.753–0.885) with a cutoff of 3.5 seconds to estimate mortality in 175 septic shock patients admitted to the ICU.

A large observational study spanning five years concluded that CRT > 3 seconds is an independent predictor of poor outcomes and mortality in critically ill patients (Sebat et al., 2020). Huang et al. (2023) identified CRT > 2.8 seconds as an independent risk factor for 28-day morbidity in critically ill patients. Other studies have associated CRT > 3 seconds with peripheral perfusion abnormalities (Dubin et al., 2020; Franzosi et al., 2020; Hernandez et al., 2019) and highlighted its value as a resuscitation goal (Hernandez et al., 2019; Lara et al., 2017; Zampieri et al., 2020).

Capillary refill time (CRT) is a critical indicator of peripheral perfusion and plays a significant role in the management of sepsis (Table 2). Prolonged CRT serves as a warning sign for severe infections.

Abnormal CRT, indicating poor peripheral perfusion, is recognized as a critical marker for serious infections. It is particularly recommended for screening children at risk of developing severe infections in outpatient care settings (Van den Bruel et al., 2010; Young Infants Clinical Signs Study, 2008). Additionally, CRT is employed as a triage tool to identify children with severe infectious diseases such as malaria, gastroenteritis, pneumonia, meningitis, and sepsis (Brierley et al., 2009; Castagno et al., 2023; Evans et al., 2006; Gove et al., 1999). Evans et al. (2006) demonstrated that CRT is an independent predictor of mortality in childhood malaria, underscoring its utility as a criterion for severe and complicated malaria. Huang et al.

(2023) reported a higher prevalence of sepsis diagnoses among adult patients with abnormal CRT following resuscitation compared to those with normal CRT (40.7% vs. 18%). Furthermore, Yasufumi et al. (2019) highlighted that combining CRT with the quick Sequential Organ Failure Assessment (qSOFA) score enhances sensitivity over qSOFA alone and improves specificity compared to the Systemic Inflammatory Response Syndrome (SIRS) criteria in predicting sepsis in patients with suspected infection. Hansen et al. (2023) suggested that incorporating CRT measurement during emergency department triage could improve sepsis diagnosis.

Prolonged CRT as Evidence of Tissue Hypoperfusion

CRT is strongly associated with the presence and severity of shock. Its pathophysiological determinants include blood volume status, cardiac output, tissue oxygenation, sympathetic tone, endothelial dysfunction, and rheological derangements. Hiemstra et al. (2019) observed that CRT measured at the sternum is independently correlated with cardiac index in critically ill patients, suggesting it may prompt further ultrasonography evaluation. CRT also correlates significantly with microcirculatory parameters such as Pv-aCO2 (Merdji et al., 2022), core-to-skin temperature gradient (Amson et al., 2020), and sublingual microcirculation parameters, including the microvascular flow index, proportion of perfused vessels, and heterogeneity index (Huang et al., 2023). Prolonged CRT is an early clinical sign of compensated shock, reflecting physiological mechanisms that prioritize blood flow to vital organs. Raimer et al. (2011) demonstrated that CRT ≤ 2 seconds was associated with central venous oxygen saturation ($ScvO_2$) $\geq 70\%$ in critically ill children. Brunauer et al. (2016) linked CRT with the pulsatility index of visceral organs (assessed via Doppler ultrasonography) during early septic shock, noting that changes in CRT paralleled alterations in the pulsatility index of the liver and intestines. Additionally, CRT is associated with lactate levels and SOFA scores (Ait-Oufella et al., 2014; Huang et al., 2023; Lima et al., 2009).

CRT in Assessing Tissue Perfusion Response

CRT has demonstrated accuracy in predicting fluid responsiveness. Over 80% of septic patients exhibit rapid improvement in CRT during fluid resuscitation, with a significant decrease observed within 6–8 minutes of initiating volume expansion and reaching its maximal drop at 10–12 minutes (Raia et al., 2022). Jacquet-Lagrèze et al. (2019) identified the change in CRT during passive leg raising (ΔCRT-PLR) as predictive of peripheral perfusion improvement following fluid resuscitation. Abnormal CRT signifies microcirculatory impairment, and improvements in CRT during volume expansion or ΔCRT-PLR provide a means to assess hemodynamic coherence (Hernandez et al., 2020a).

CRT-Guided Fluid Resuscitation

Shock management progresses through phases of salvage, optimization, stabilization, and de-escalation, each requiring tailored approaches. Standard fluid therapy and fluid restriction may both be suboptimal (Meyhoff et al., 2022), necessitating personalized strategies (De Backer et al., 2022). For example, during the optimization phase, the proportion of fluid responders diminishes, while the risk of adverse events increases (Hernandez et al., 2019). CRT facilitates the early detection

of tissue hypoperfusion, hypoxia, and fluid non-responsiveness, enabling timely intervention to prevent organ damage. While CRT cannot identify the etiology of tissue hypoperfusion, it provides critical insights into perfusion response and guides resuscitation in sepsis patients (Cecconi et al., 2019; Dubin et al., 2018; Hernandez et al., 2014; Kattan et al., 2020a). Compared to lactate-targeted resuscitation, CRT-guided strategies have been shown to reduce organ dysfunction and mortality (Hernandez et al., 2019; Zampieri et al., 2020). CRT is a simple, rapid, and non-invasive measure that can be assessed frequently, showing faster improvement than lactate during shock resuscitation (Kattan et al., 2020b). Achieving CRT < 3 seconds may serve as a key guideline for fluid resuscitation, whereas prolonged lactate normalization could lead to excessive fluid administration, exacerbating interstitial edema, venous congestion, and oxygen diffusion impairments (Chandra et al., 2022).

Predictive Value of CRT

CRT exhibits varying normalization rates compared to other perfusion markers during fluid resuscitation. Hernandez et al. (2012, 2014) found CRT normalizes within 6 hours, earlier than lactate and sublingual microcirculatory parameters, which may take over 24 hours. Raia et al. (2022) observed a significant reduction in CRT following resuscitation, with longer baseline CRT correlating to greater reductions. Morocho et al. (2022) reported that the area under the curve (AUC) for predicting mortality in septic shock patients was higher for CRT measured 6 hours post-ICU admission (0.819) compared to admission CRT (0.666). Prolonged CRT at 6 hours signifies unresolved tissue hypoperfusion and an elevated risk of adverse outcomes. Studies have demonstrated significant differences in mortality between patients with normal and abnormal CRT after resuscitation (Ait-Oufella et al., 2014; Bakker and Hernandez, 2020; Hernandez et al., 2019). For instance, Lara et al. (2017) reported increased hospital mortality (63% vs. 9%, $p < 0.001$) and adverse outcomes (88% vs. 20%, $p < 0.001$) in hyperlactatemic septic patients with prolonged CRT compared to those with normal CRT after initial resuscitation. Persistent abnormal CRT post-resuscitation signifies a severe clinical phenotype characterized by greater organ dysfunction and lower survival rates (Hernandez et al., 2020b). Normalization of CRT reflects improved microcirculation, reduced adrenergic tone, and enhanced systemic blood flow.

CRT also predicts adverse outcomes in critically ill patients. Van Genderen et al. (2014) associated prolonged CRT with higher complication rates in major abdominal surgery. Merdji et al. (2022) noted CRT > 3 seconds as a marker for the need for veno-arterial extracorporeal membrane oxygenation (VA-ECMO) or early 90-day mortality prediction in cardiogenic shock patients.

Clinical Application of CRT

CRT assessment involves some subjectivity and interobserver variability due to differences in experience, training, and measurement techniques. To reduce variability, CRT should be measured by trained physicians using standardized methods in patients without dark skin or peripheral vascular disease, while accounting for ambient factors. As a qualitative variable (CRT > 3 seconds or not), CRT serves as a

red flag for severe infections, a reliable triage tool, and a crucial resuscitation target. As a quantitative measure, CRT provides precise peripheral perfusion monitoring during resuscitation and reflects fluid responsiveness (Fig. 2).

Conclusion

Capillary refill time (CRT) serves as a vital non-invasive indicator of peripheral perfusion, offering significant clinical insights into tissue hypoperfusion, fluid responsiveness, and shock management in sepsis patients. Despite its potential, CRT assessment remains inconsistent due to variability in technique, interobserver differences, and a lack of standardized protocols. Enhanced training, adherence to standardized methods, and the integration of advanced tools can improve the accuracy and reliability of CRT measurements. Nurses play a pivotal role in utilizing CRT for early identification of sepsis, guiding resuscitation strategies, and monitoring patient outcomes. Incorporating CRT into routine practice empowers nurses to make timely interventions, thereby improving the prognosis of critically ill patients.

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