Review Article

Core to Skin Temperature Gradient in Septic Shock Patients and its Impact on Mortality: A Review

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Abstract

Sepsis is a life-threatening organ dysfunction resulting from a dysregulated host response to infection, consistent with the Sepsis-5 consensus definition. Septic shock should be defined as a subtype of sepsis in which particularly severe circulatory, cellular, and metabolic abnormalities are associated with a higher mortality risk than sepsis alone. Infection-induced release of bacterial toxins, inflammatory mediators, cytokines, and vasoactive substances increases capillary permeability and leads to extensive plasma leakage, resulting in insufficient effective circulating blood volume and microcirculatory dysfunction., can cause electrolyte imbalances, acidosis, and other changes in the internal environment. Septic shock is associated with alterations in peripheral blood flow, and core-to-skin temperature gradients depend on cutaneous blood flow and microcirculatory function. Infrared thermography is a non-invasive technique that uses an infrared camera to record the infrared radiation emitted by the body, from which temperature is derived. We, therefore, hypothesized that high core-to-skin temperature gradients correlate with septic shock and mortality.

Keywords: Sepsis, Septic Shock, Mortality, ICU, Core temperature, Skin temperature, Thermography.

Introduction

Sepsis is one of the leading causes of death in hospital emergency departments and intensive care units (ICUs). Microcirculatory disturbances play an important role in the physiopathology of septic shock.[1,2]. Microcirculatory monitoring can be performed directly at the patient's bedside (spot score, diuresis, skin temperature gradient) or by state-of-the-art methods (sublingual flow darkfield (SDF) video microscopy to assess microvascular perfusion. [3,4] and indirectly using near-infrared spectroscopy (NIRS) to primarily assess muscle perfusion and detect global oxygenation variations in tissue perfusion.[5] Skin perfusion can be easily assessed clinically by examining leg mottling patterns,

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capillary refill times, or skin temperature. These have been previously associated with the course of sepsis. [6] Infrared thermography (IT) enables accurate non-contact measurement of surface temperature. To avoid ambient temperature effects, measuring the temperature gradient (TG) between two points is much more important than single-point temperature measurement.[7] We want to know whether the core-to-skin temperature gradients (CTSG), measured by infrared thermograph (IT), represent a predictive factor of mortality during septic shock.[8]

The essential components of sepsis are:

- life-threatening conditions and urgent action are required.
- Organ dysfunction or worsening of existing organ dysfunction.
- Suspected or documented infection.
- Inappropriate host response to infection.

Pathophysiology of sepsis: Sepsis causes profound changes in microcirculation and microcirculation, characterized by reduced peripheral vascular resistance, maldistribution of tissue blood flow, and disruption of microcirculatory perfusion.[9] Increased vascular permeability is a common feature of sepsis, leading to interstitial edema and fluid retention. The imbalance between vasoconstrictors, vasodilators, and oxidative stress at the endothelial level has received considerable attention as a key factor in the development of MODS. [10] During sepsis, the production enzyme, inducible nitric oxide synthase (iNOS), exhibits a heterogeneous expression pattern, while overall nitric oxide production increases, resulting in different local nitric oxide concentrations occurs. An uneven distribution of nitric oxide production may contribute to uneven perfusion patterns.[11] (Figure No-1)

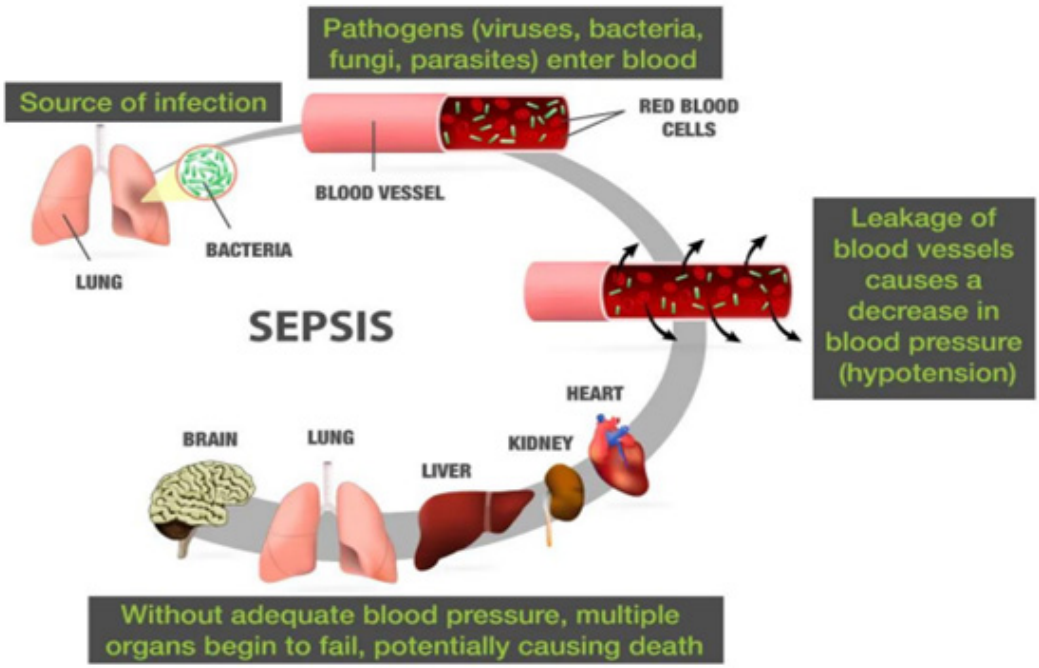

Figure 1: Pathophysiology of sepsis [11]

Septic shock is defined as a subtype of sepsis in which particularly widespread circulatory, cellular, and metabolic abnormalities significantly increase mortality [12]. [Figure No-2]

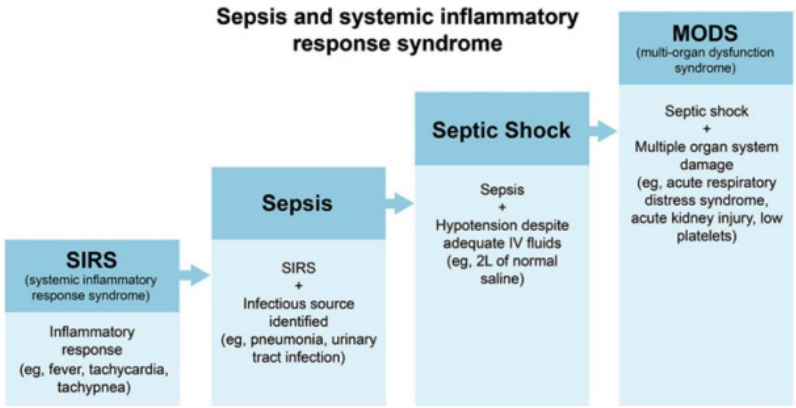

Figure No-2 Septic shock MODS [12]

Clinical Criteria for Sepsis: Suspected or documented infection with a sharp rise >2 SOFA points. [13]

Warning signs and symptoms are: fever or low temperature and chills• clouding of consciousness• dyspnea/rapid breathing Increased heart rate Weak pulse/low blood pressure, low urine output• cyanotic or mottled skin• cold extremities• Extreme physical pain or discomfort [14]

Impaired tissue perfusion: - 1. High serum lactate level (>2 mmol/L) 2. Delayed capillary refill time 3. Mottled skin Suspicion of sepsis is an important first step toward early detection and diagnosis.[15]

SOFA-Scoring – The Sequential Organ Failure Assessment] is a scoring method used in sepsis, and septic shock to assess organ function introduced by Sepsis 3 in 2016. [16]

Sepsis and its Consequences

Vascular dysfunction associated with sepsis- Septic shock is primarily a paraplegic condition with dilation of arteries and veins due to the inability to contract vascular smooth muscles. [17] Virologic shock is associated with increased nitric oxide (NO) production, activation of K-related ATP channels leading to hyperpolarization of muscle cell membranes, and inducible nitric oxide synthase with increased production of natriuretic peptides. Arterial dilatation leads to systemic hypotension. [18] [Figure No-3]

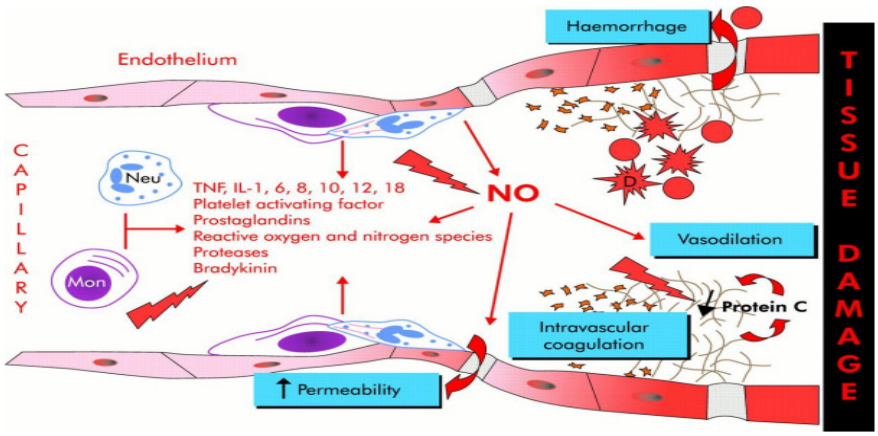

Figure No-3 Sepsis and its Consequences [18]

Skin Temperature vs Core Temperature

Core temperature is the ideal temperature for internal organ function, but we do not usually examine the heart or brain to determine a person's body temperature. [19] Skin temperature can be as much as two degrees lower than internal temperature, but it is close enough to give a good idea of what is going on inside. [20]

Infrared Thermography[IT]-

The use of IT is possible to measure surface temperature without contact. The measure of the temperature gradient between two points seems to be more relevant than a single-point temperature measure. It has the advantage of being non-invasive, easy to use, and cost-effective, which is why it has been advocated to monitor peripheral perfusion. [21] Calculating a gradient between the two sites can be done with the measurement of peripheral and core temperature, with values between 3 and 7 C considered normal. It is a painless, nonionizing, contact-free diagnostic technique. Thermography can be used as a medical tool because of the high emissivity of skin. It has been used to assess organ perfusion. [22] Changes in skin temperature can be caused by hemodynamic instability and its associated decrease in peripheral perfusion. The use of IT for the assessment of peripheral perfusion in critical conditions presents a potential interest. The study aimed to see if IT could be used to detect variations of peripheral perfusion in a patient. [23] [Figure No 4A & 4B]

Figure No 4A & 4B Infrared Thermography [IT] [23]

Figure No 4A

Infrared Themography

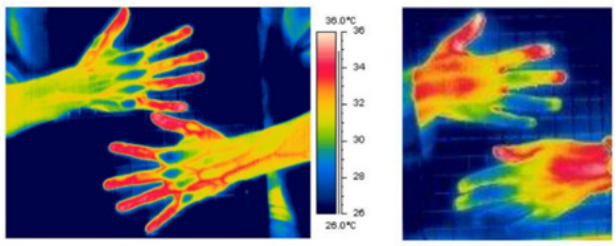

Figure No 4B

Discussion

The current article is focused on evaluating the prognostic potential of the core-to-skin temperature gradient measured with an infrared thermograph (IT) and an esophageal temperature probe during septic shock. The main finding was the association between core-to-index temperature gradient and day 8 mortality in these patients. [23,24] A secondary outcome was the comparison of this temperature gradient with capillary refill time (CRT) which is also a hypoperfusion parameter of shock. All patients included in the study had septic shock according to the definition of sepsis. [25] This selection meant that all patients had organ failure, which differs from other studies that have examined the association between signs of skin hypoperfusion and mortality so the studies having patients with less severe disease may not have similar results as ours. [26] According to Bourcier et al. (2016), who conducted a study on 103 patients, the gradient between toe and room temperature was shown to correlate significantly with tissue perfusion markers such as urine output, arterial lactate level, mottling score, and knee capillary refill time (CRT). [27] In previous studies, patients suffered from cirrhosis, ARDS, pancreatitis, and vascular diseases known to have altered cutaneous blood flow (Zerem E. et al 2014) and we assume the same in our study. We chose to use the criteria for early mortality (day 8 mortality) because later mortality (day 14, day 28 mortality) was caused by factors, most likely due to co-morbidities and infections acquired in the ICU. It was also influenced by several other factors such as disease and complications and severity of the early acute circulatory failure. [28] Evaluation of skin temperature in circulatory failure began in 1969 with his work by Joly et al. He found that cold toes were associated with shock severity. [29] In 2001, Kaplan et al. showed higher lactate levels in patients with cold extremities in the intensive care unit. [30] In 2009, Lima et al concluded that In ICU patients, subjective assessment of peripheral blood flow (including CRT and extremity cooling) was found to be associated with more severe organ dysfunction and higher lactate levels. [31] Subsequently, Ait-Oufella et al. studied peripheral perfusion markers of sepsis. [32] They found that there is a correlation between mottling score capillary refill time (CRT), and toe-to-room temperature gradient [33] in sepsis mortality. Recently, Dumas et al. have shown that there is a high prognostic value of mottling score for 14-day mortality in septic patients, whatever

inotropic support and other perfusion parameters. Mottling score variations during resuscitation are also predictive of mortality. [34,35] In addition, Bridget et al. in their systemic review concluded that the use of extremity skin temperature as a "proxy" for hypoperfusion cannot be validated or recommended due to the paucity of definitive evidence. [36] Schey et al. in their review included 26 studies that primarily examined skin temperature as a marker of hemodynamics after cardiac surgery and concluded that the evidence is lacking and more prospective studies are needed. [37] Infrared thermography (IT) was chosen because promising results had already been published in an experimental model in pigs: infrared thermograph has the ability for detecting peripheral perfusion disorders secondary to hemodynamic variations according to Magnin M et al. 2020(92) In most studies such as Bourcier S et al.2016 and Joly HR et al. 1969 - the core-to-skin temperature gradient is taken as the core-to-toe gradient. [38,39] This gradient was also evaluated in our study, but it was computed differently from previous studies. Indeed, the skin temperature in our study was measured on the dorsal side and not on the ventral side, as in the historical study of Joly et al. [39] On analysis of our data and statistical evaluation, and comparing with data of other authors, we conclude this prospective observational study of critically ill patients with severe infections, core to skin temperature gradient reflected disease severity and hence predicts 8th-day mortality in septic shock patients. The core-to-skin temperature gradient is better in predicting the 8th-day mortality than capillary refill time in septic shock patients. [40]

Limitations of the study: Our study had several limitations

I. The sample size was small. Larger sample size and a multicenter study with high precision and accuracy could be recommended for a more reliable interpretation of the results

II. The results are limited to a single tertiary care center and may not be generalizable to all areas. Therefore, they cannot be generalized to a larger population

In addition, due to covid-19 the limited influx of patients to our tertiary care center, it was difficult to generalize our study to a larger group

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Conflict of interest: There is no conflict of interest.

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Ethical clearance: It is a retrospective observational study hence no ethical approval is required.

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