

# Microcirculation: An open area for nursing research

*Elizabeth A. Sorrentino, PhD, RN*  
*Adjunct Nurse Researcher*  
*Veterans Administration Medical Center*  
*Miami, Florida*

*Harvey N. Mayrovitz, PhD*  
*Chief, Microvascular Studies Unit*  
*Miami Heart Institute*  
*Miami Beach, Florida*

**T**HE CONCEPT of basic research is usually associated with seeking new knowledge<sup>1</sup> and with the development or refinement of theories.<sup>2</sup> This may be distinguished from clinical research, which deals with practical application and implementation of theories in existing situations.<sup>3</sup> The majority of studies conducted by nurses is applied research.<sup>1</sup> This article discusses the study of microvascular physiologic and pathologic phenomena that are directly relevant to nursing interests. In addition, possible applications for nursing research are proposed using the study of skin microcirculation.

## **A NEW LEVEL OF INQUIRY: MICROCIRCULATION**

The importance and function of the cardiovascular system are known to many nurses and, needless to say, well-emphasized. It is,

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however, at the microcirculatory level that nutritive exchange occurs. Indeed, the process of local homeostasis depends on the specific properties of the microvasculature.<sup>4</sup> Tissue viability and function are dependent on microcirculatory hemodynamics, which include the pressure and flow within the microvessels. The complex microcirculatory characteristics in each organ system affects the outcomes of many therapeutic interventions. The study of skin microcirculation allows the examination of the dynamics of blood flow under physiologic and pathologic conditions.

The flow of blood through the skin is presumed to be an indicator of the general health and developmental state of the patient.<sup>5</sup> Early in their education, nurses are instructed to observe the skin for warmth, tenderness, presence of dryness, or edema. Warmness or coolness to touch has been commonly used to indicate skin status. Skin temperature, though, depends on many factors and is a crude index of circulation. It does not necessarily reflect microcirculatory status; hence, it is not the best method to evaluate skin microcirculation in the individual patient.<sup>6</sup>

Nursing interventions, such as turning the patient every 2 hours, are directed toward the maintenance of skin integrity to prevent pressure sores. Blood flow through the skin is likely to be affected by acute or chronic alterations in circulatory or neurologic functions, nutritional states, and the aging process. Thus, it is a factor to consider in enhancing positive patient outcomes. The level of nursing inquiry, though, requires a step beyond gross assessment of skin warmth or coolness to touch.

Microcirculation has gained considerable attention with regard to its role in tissue

healing associated with injury from surgery, ischemia, burn, or pathologic processes such as diabetes. The resulting microcirculatory changes in blood flow, flow distribution, and rheology of the blood, together with its cellular components, can lead to irreversible tissue damage.<sup>7</sup> In microvascular reconstructive surgery, investigation at this level is of importance because of the need to maintain patent microvascular anastomoses, as in replanted tissues or free-flap transfers.<sup>8</sup> Inflammatory states are known to have underlying microvascular events such as accumulation of polymorphonuclears (PMN), which may increase hindrance to flow in the capillaries.<sup>9</sup> The role of capillary plugging by granulocytes has been proposed as a mechanism responsible for the no-reflow phenomenon and, together with oxygen-free radical formation and lysosomal enzyme activity, may constitute the sources for the origin of ischemic injury as well as other microvascular occlusive disease states.<sup>10</sup> In diabetes, one of the associated circulatory problems is confined to the nutritive segments of the circulatory system (ie, capillaries and small venules). Investigations in this area can provide important information for the interpretation of the microvascular pathophysiology in this disease.<sup>11</sup>

There are microcirculatory changes associated with human disease states such as diabetes, hypertension, and peripheral vascular and cerebrovascular diseases. The study of microcirculation in humans can be done using a variety of noninvasive methods such as transcutaneous  $Po_2$  measurements, laser doppler flowmetry, dynamic capillaroscopy, and vital capillary microscopy. These non-invasive methods, which are briefly described in the following paragraphs, have been used

to study the skin microcirculation in patients with alterations in blood pressure, tissue perfusion, and other disease states.

### METHODS FOR THE STUDY OF HUMAN SKIN MICROCIRCULATION

There are two different vascular beds in human skin microcirculation: the nutritional capillaries and the thermoregulatory bed. Normally, less than 10% of blood flows through the nutritional capillaries and more than 90% flows through the thermoregulatory bed.<sup>10,11</sup> Most methods in the evaluation of blood flow do not allow differential measurements in different compartments.<sup>6,12</sup> During decreased or zero blood flow, the structure and filling of capillaries change. Often, during or following ischemia, there is decrease or loss of microvessel tone and capillaries may become engorged with blood. Associated with prolonged ischemia are edema and capillary hemorrhages from plasma or cell leakage. Ultimately, the skin may not survive and gangrene or necrosis develops.<sup>13</sup> Studies on the dynamics of blood flow help in gaining insight regarding factors affecting outcomes of preventive interventions or therapeutic measures. One method that is known to many critical care nurses for its clinical application is the transcutaneous  $P_{O_2}$  measurement, which has been widely used for patients on respiratory assist devices.

Transcutaneous  $P_{O_2}$  measurement has been traditionally used in neonates.<sup>14</sup> Its use in adults for evaluating skin blood supply and viability,<sup>14-19</sup> as well as vasomotor responses in diabetic children,<sup>20</sup> has been reported. The healing of both pathologic and surgical wounds is strongly dependent on adequate

skin blood flow and oxygenation. Transcutaneous measurement of  $P_{O_2}$  is useful in the functional study of vascular pathology.<sup>21</sup> Regional skin oxygenation studies aid in the diagnosis of ischemia and allow maximal conservation of tissue in limb salvage situations.<sup>20</sup> This is particularly useful in the analysis of microvascular hemodynamics and local tissue  $P_{O_2}$  prior to and during a prolonged period of ischemia in skin.<sup>22</sup> It has been used to determine the functional relation between microcirculation and oxygen supply.<sup>23</sup> For purposes of following oxygenation of blood, this method is quite accurate.<sup>24</sup> It does have disadvantages, however: it is an indirect method, and it is influenced by skin properties, composition of the microvascular bed, and delivery of oxygen across the capillary wall.<sup>25</sup>

Laser doppler flowmetry is a noninvasive measurement of skin blood perfusion<sup>26</sup> within a tissue volume from the skin surface to the depth of approximately 1 mm. This allows the evaluation of skin circulation in patients with diabetes, peripheral vascular disorders,<sup>27</sup> and changes associated with burns.<sup>28,29</sup> Rhythmic variations of microvascular flux have been studied at the forefoot of patients with arterial occlusive disease by laser doppler flowmetry<sup>30</sup> and at other skin sites. In severely ischemic lower limbs, the skin response to changing posture from lying to standing is a diagnostic flush. Allen and Goldman<sup>31</sup> investigated this by measurements of microcirculation using the noninvasive laser doppler technique. The determination of flow initiation in the microcirculation after a period of arrest due to externally applied counterpressure can be done. In diabetic neuropathy, this method has been used to measure the response of skin capillary blood

flow to local thermal stimulation<sup>32</sup> and to compare patterns of cutaneous blood flow in the forearms of patients with stable sickle cell disease.<sup>33</sup> Skin blood flow velocity in healthy adults has been measured using laser doppler velocimetry.<sup>34</sup> One drawback is that the equipment responds to all moving objects in a limited skin volume. There is uncertainty as to the extent the measurement includes nonnutritional flow components from the underlying thermoregulatory vessels.<sup>34</sup> Nonetheless, the method is the one of choice for assessment of skin microperfusion.

Dynamic capillaroscopy is a technique that employs videoanalysis through a microscope television system and measures blood velocity directly in single skin capillaries of the nailfold.<sup>34,35</sup> Detailed description is provided by Fagrell.<sup>36</sup> The uses of dynamic capillaroscopy include the study of nutritional skin capillaries and evaluating the risk of skin necrosis in patients with peripheral ischemia.<sup>13</sup> The disadvantages that may be encountered include<sup>35</sup> (a) the skin is not transparent enough, (b) the capillary loop is too short to obtain the necessary measurement, (c) there is inadequate contrast of the flowing erythrocytes, and (d) there is difficulty in maintaining capillaries in focus.

Vital capillaroscopy is a direct, noninvasive technique that allows the examination of the skin capillaries using an ordinary light microscope with a magnification of 10x to 60x.<sup>6,35,37-39</sup> It has been widely used to examine the effect of therapeutic procedures aimed at improving nutritional circulation in patients with risk of skin necrosis,<sup>11,35,37</sup> such as patients with diabetes and peripheral vascular disease. Capillary examinations of the nailfolds are useful in evaluating Raynaud's phenomenon<sup>40</sup> and other connective tissue

diseases.<sup>41</sup> Similar examinations may be done in other skin regions such as the head, arms, or legs. Vital capillaroscopy has the advantage of allowing the noninvasive examination of skin microcirculation in undisturbed preparations for chronic studies.<sup>35</sup> The disadvantage of this technique is the subjective evaluation of capillary changes, and, thus, it is at best semiquantitative. But, with the use of a standardized classification system, this technique proves to be beneficial.<sup>42</sup>

The methods for the study of human skin microcirculation have been discussed briefly. Transcutaneous Po<sub>2</sub> measurements, laser doppler, dynamic capillaroscopy, and vital capillaroscopy are instrumental in examining the pathophysiology of major disease states at the microcirculatory level. Also alluded to are the associated advantages and disadvantages of each technique that need to be considered. Alternatively, answers to basic questions with regard to capillary morphology and flow dynamics in both physiologic and pathologic conditions can be explored, which open new avenues for nursing research.<sup>43</sup>

## MICROCIRCULATORY NURSING RESEARCH

Many nursing concepts or abstractions, such as pallor, blanching, cyanosis, granulation, or mottling, are manifestations of certain disease states. Ischemia of skeletal muscle and skin is a common clinical problem that occurs in pressure ulcers and following reconstructive vascular surgery.<sup>7</sup> The supply of blood to an injured area is crucial for tissue regeneration in the wound. Certainly, this can be examined at the micro-

vascular level. Nursing treatments have been directed at prevention of further tissue damage, as well as facilitating the healing process. Thus, the nurse can explore alternative nursing interventions based on research.

Nursing observations and interventions in the management of burn injury play important roles in the prevention of complications. The study of microcirculatory response to burn injury can include the pathology of inflammation in an experimental burn wound. The possibility exists to describe the dynamic changes of microcirculation as related to the final degree of injury following a burn. Increase or decrease in edema (skin water content) in burned areas can be quantified and measured as a function of time. In diabetes, the skin circulation is altered to the extent that poor skin turgor, dryness, and lesion formation occurs. These phenomena can be observed, quantified, and the effect of interventions such as emollients, compresses, or pharmaceuticals assessed. The methods for studying skin microcirculation that can be used have been described earlier to assist in the selection of appropriate techniques in nursing inquiry.

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