EDITOR'S CHOICE

# The Effect of Skin Pigmentation on Determination of Limb Ischemia

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**Purpose** Timely identification of tissue ischemia is critical, both in the traumatized limb and following free tissue transfer. The purpose of this study was to determine if skin pigmentation affects the ability to detect limb ischemia.

**Methods** We conducted a study of healthy controls exposed to limb ischemia. The subjects were classified based on skin pigmentation using a defined skin type assessment tool, a visual color scale, and self-description of race. Participants were randomized by limb and tourniquet status; surgeons were blinded to both. Ischemia was induced by tourniquet insufflations, and board-certified orthopedic and plastic surgeons who had completed an accredited hand surgery fellowship conducted physical examinations. The surgeons monitored the forearms at 2, 6, and 10 minutes based on appearance of ischemia, capillary refill, and color in 3 locations on the limbs (posterior interosseous artery flap skin territory, radial forearm flap skin territory, and the digits).

**Results** We found a significant decrease in the ability to detect ischemia in participants with increased skin pigmentation, as documented by all metrics, when evaluating the posterior interosseous artery and radial forearm flap skin territories at all time points. For example, when monitoring the posterior interosseous artery flap with the tourniquet insufflated at time 10 minutes, 92.9% of Caucasians were correctly identified as being ischemic whereas only 23.3% of African Americans were correctly identified.

**Conclusions** Skin pigmentation significantly affects the identification of an ischemic limb/skin flaps on physical examination. Whereas the standard treatment for monitoring of free tissue transfer is clinical examination, that may not be sufficient for patients with increased skin pigmentation. Surgeons should exercise particular vigilance during physical examination of a potentially ischemic limb/skin flaps with greater skin pigmentation. *(J Hand Surg Am. 2017;■(■):■−■. Copyright © 2017 by the American Society for Surgery of the Hand. All rights reserved.)*

**Type of study/level of evidence** Diagnostic II.

**Key words** Skin pigmentation, ischemia, tourniquet.

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THE CLINICAL EFFECT OF NOT recognizing ischemia in a posttraumatic or postoperative free tissue transfer can be devastating. Time to identification of flap ischemia is critical for revascularization to be successful. According to Goodstein and Buncke,[1] the success of reexploration is inversely related to the time between detection of ischemia and return to the operating room. As the time of ischemia increases, tissue viability decreases. The no-reflow phenomenon suggests that, after 12 hours of ischemia, there is a point of irreversibility and ultimate flap death.[2] In a study by Disa et al,[3] there was a 0% salvage rate in unmonitored flaps, thereby stressing the importance of clinical monitoring.

There have been several advances in postoperative monitoring of flaps to include implantable Doppler probes, laser Doppler flowmetry, near-infrared spectroscopy (NIRS), quantitative fluorimetry, and digital photography,[4] but they have all been compared with clinical examination as the reference standard.[5,6] The optimal test to assess the efficacy of a monitoring system is the ability to recognize a flap at risk promptly to allow for a rapid return to the operating room and salvage of the flap without resulting in unnecessary returns to the operating room. Whereas there have been studies demonstrating devices that could detect compromise earlier, there has been no associated increase in flap salvage rates, which may limit widespread implementation.[7–10] Clinicians may have concerns with using additional monitoring, such as increased cost and labor time, technical difficulty, and possibly increased rate of unnecessary returns to the operating room. These are likely some of the reasons that clinical examination remains the most commonly used method of postoperative skin and tissue perfusion monitoring.

Although anecdotally it has been suggested that it is difficult to clinically monitor flaps in patients with increased skin pigmentation, very little has been published on the effect of skin pigmentation on clinical evaluation. We are aware of 1 study in which investigators examined the effect of racial differences regarding ischemic flap complications.[11] The investigators looked specifically at pedicled versus free abdominal flaps for breast reconstruction and found that African Americans undergoing pedicled transverse rectus abdominis myocutaneous flaps are at increased risk for grade IV fat necrosis but not mastectomy or partial flap necrosis. The authors speculated that the results could be attributed to difficulty in postoperative examination owing to skin color or the higher rates of diabetes and body mass index (BMI) lending to higher rates of ischemic complications, but they did not specifically examine the cause. It is also possible that the fat necrosis itself was due to patient comorbidities or other factors unrelated to actual ischemia.

Skin pigmentation can be determined in several ways, both objective and subjective. There are numerous scales used to classify skin types. They include, but are not limited to, the Fitzpatrick Scale,[12,13] von Luschan color chart,[14] Taylor Hyperpigmentation Scale,[15] Kawada Skin Classification Scale,[16] Lancer Ethnicity Scale,[17] Goldman World Classification of Skin Type,[18] and the Roberts Skin Type Classification System.[19] Of these, the Fitzpatrick Scale is considered the reference standard.[20] It is used to determine the patient's phototype with a questionnaire that emphasizes the color of the patient's skin and eyes as well as their ability to tan or sunburn. It was initially described in 1975[21] with only 4 types, but was expanded to 6 in 1988.[13] Although it is the standard scale used for classifying skin type, it is biased by self-reporting. A more objective method would include a visual scale and matching a patient's skin color to a color chart, especially because other authors have stated that the best standard for assessing skin pigmentation is through visual inspection.[15,22] One such color chart is that developed by von Luschan that allows for 36 different skin colors (Appendix A; available on the *Journal*'s Web site at www.jhandsurg.org).[14] The Fitzpatrick Scale and the von Luschan color chart have been correlated with objective reading from narrow-band reflectance spectrophotometer.[22] Some of the difficulties with using the spectrophotomer itself in the clinical setting are expense, availability, and unproven applicability.

The purpose of our investigation was to determine if there is a difference in the diagnosis of ischemia related to skin pigmentation. If skin pigmentation significantly affects clinical examination with regard to ischemia, then it would follow that a more objective means for flap monitoring is necessary, especially for patients with certain pigmentation. The null hypothesis was that there is no difference in the ability to determine ischemia in a healthy limb by physical examination regardless of the limb skin pigmentation.

## MATERIALS AND METHODS

This study was approved by our institutional review board. A study of healthy controls exposed to limb ischemia via tourniquet was conducted to determine if pigmentation adversely affects determination of ischemia based on physical examination. We enrolled healthy volunteers that were recruited from the local area via e-mail, flyers, and word of mouth to undergo application of a tourniquet followed by physical