MEGA JOURNAL OF CASE REPORTS

OPEN ACCESS

Review Article

Compiled Date: July 23, 2025

About the Role and Current Impact of Hyperspectral Imaging in Plastic Surgery - A Brief Abstract

Thomas Wild[1,3*], Jonas Paul Besch[3], Jörg Marotz[3] and Ivo Buschmann[1,2]

[1]Department for Angiology, Center for Internal Medicine, Deutsches Angiologie Zentrum (DAZB), Brandenburg Medical School (MHB) Theodor Fontane, University Clinic Brandenburg, Brandenburg/Havel, Germany

[2]Faculty of Health Sciences, Joint Faculty of Brandenburg University of Technology Cottbus-Senftenberg, Brandenburg Medical School Theodor Fontane, University of Potsdam, Potsdam, Germany

[3]Institute for Food Technology, Biotechnology and Quality Assurance "Fritz Höppler" e.V., affiliated institute of University of Applied Sciences Anhalt; Köthen, Germany

[*]**Corresponding author**: Thomas Wild, Department for Angiology, Center for Internal Medicine, Deutsches Angiologie Zentrum (DAZB), Brandenburg Medical School (MHB) Theodor Fontane, University Clinic Brandenburg, Brandenburg/Havel, Germany, Tel: 491754191566

Introduction

Hyperspectral Imaging (HSI) has emerged as a transformative technology especially in terms of diagnostics in medicine and therewith also in plastic surgery. HSI captures a wide spectrum of light wavelengths beyond the visible range and those of other clinically used imaging technologies such as MSI (Multispectral Imaging) and NIRS (Near-Infrared-Spectroscopy). Therefore the amount of acquired data increases drastically and can provide broader information to support clinicians regarding tissue viability assessment, monitoring of (burn-) wound healing and surgical intervention guidance. The following article aims to provide an overview of the current scientific understanding and HSI applications already used (and in the making) focusing on burn care, flap surgery and wound management while also mentioning possible applications in the discipline.

Fundamentals of Hyperspectral Imaging

HSI, originally invented for assessing soil quality and geological analysis of examined land, gained interest in the field of medicine in the past 30 years for good

reason. HSI involves collecting and processing information from across the electromagnetic spectrum normally ranging between 400-1000 nm which enables this technology to provide information in depth of the skin estimated from 5 to 8mm under skin level. By this HSI can collect information on the microcirculation of skin or other tissue with blood flow. Since every biochemical structure is unique in its traits of absorbing and re-emitting light, statements on perfusion and distribution of tissue components can be made. To gain the remission spectrum, skin areas are getting illuminated with normal white light throughout the imaging process, while the re-emitted wavelengths of the skin are getting collected. Usually the imaging process takes no longer than 5 seconds, delivers accessible data while still being non-invasive.

Applications in Burn Care

The classification of burn depth and severity remains uncertain and often subjective depending on the experience of the burn surgeon but is crucial for determining the appropriate treatment strategy. In recent years different approaches for the assessment of burn depths and severity categorisation have been published. Hyperspectral Imaging is considered a promising technology to be used for burn classification due to its abilities of tissue evaluation. Parasca et al. [1] suggested object-oriented wound mapping based on HSI for better surgical guidance performing with high accuracy, precision, sensitivity and specificity all above 95%. Schulz et al. [2] suggested a skin layer based assessment tool for perfusion level of burned skin to predict the healing process and burn severity within the first days after burn, performing with a sensitivity of 92% and a specificity of 71%. But still some work has to be done since Wild et al. [3] proceeded on this approach and found that the deepening process in the first few days even hinders HSI in predicting wound dynamics to certain extent. Nevertheless Hyperspectral Imaging facilitates early and precise decision-making regarding the need for surgical intervention, such as debridement or grafting, ultimately improving patient outcomes and in-time and objective data-based reevaluation of burn wounds in the future.

Enhancing Flap Surgery

Flap procedures, which involve the transfer of tissue with its blood supply to reconstruct defects, are fundamental in plastic and reconstructive surgery. The success of these procedures heavily relies on the viability of the transplanted tissue. By detecting early signs of ischemia or compromised blood flow, HSI enables timely interventions to salvage at-risk flaps, thereby reducing the incidence of flap failure and associated complications. Kohler et al. [4] stated that HSI can play a significant role in intra- and post-operative flap perfusion and viability screening, since it provides essential parameters like hemoglobin oxygenation and perfusion rate c what seems to make HSI superior to LSI or others. According to Schulz et al. [5] HSI is more sensitive to free-flap failure within the first 24 h after transplantation but clinical examination has been found superior to HSI within the first 72 h post surgery. In the end hyperspectral imaging can already have an impact in assisting clinical examination of flaps, while still not being gold standard on its own. Yet it holds a good prospect to emerge more impactful in the next few years with ongoing research and technology development.

Advancements in Wound Management

The healing of wounds is directly related to perfusion status of the wound bed. That is why the examination of the related parameters should be key to the prediction of wound healing and the decision on most suitable wound care. HSI can supply such data about tissue oxygenation, hemoglobin concentration, and the presence of necrotic tissue by multiple parameters instantly available after image taking. Daeschlein et al. [6] found it suitable for wound monitoring in multiple cases. This direction is supported by the reviewing from Seiko et al. [7] according to which HSI can highly impact and enhance wound prevention and treatment but still needs point of care testing and comparison based evaluation with other diagnostic tools.

Perspectives in Aesthetic Surgery

Even in the field of aesthetic surgery, HSI can provide guidelines for treatment evaluation, monitoring, healing assessment, and visualization. Almost no reliable research has been conducted specifically to test HSI for aesthetic applications. However, drawing on basic HSI parameters, the previously mentioned TWI, in combination with inflammation-related HSI markers, can aid in identifying suitable sites for hyaluronan or botox injections in facial areas. TWI indicates the distribution of tissue water therefore being crucial for edema and general stasis detection. Moreover, HSI can map collagen [8] and distinguish between types I and III, both of which are crucial for evaluating the scarring process. Additionally, the integration of HSI with 3D photography for improved skin surface, depth, and breast surgery evaluation is a promising tool in aesthetic surgery and treatment consultation, as already implemented in some practices.

Applicability in Angiology

Beyond its established role in flap monitoring and burn assessment, Hyperspectral Imaging (HSI) is increasingly being recognized as a powerful tool for visualizing arteriogenesis—the body's most relevant endogenous mechanism to improve blood flow through collateral vessel formation. Arteriogenesis, distinct from angiogenesis, involves the remodeling and active growth of pre-existing arteriolar connections into functional collateral arteries in response to increased shear stress. In this context, HSI offers a non-invasive approach to detect subtle changes in oxygen saturation, hemoglobin distribution, and tissue perfusion patterns associated with arteriogenesis. Pioneering work by Wolfgang Schaper and colleagues demonstrated the potential of arteriogenesis in the context of perfusion patterns and microvascular activation in ischemic tissue regions post-operatively-particularly in patients undergoing Coronary Artery Bypass Grafting (CABG), where so-called "sleeping collaterals" are being trained pre operation. HSI allows for real-time, intraoperative imaging of these changes, which are often missed by conventional imaging modalities. In reconstructive procedures involving ischemic limbs or failed flaps, the ability to track collateral vessel recruitment via HSI may provide critical insight into the success or failure of conservative versus interventional therapeutic strategies.

Discussion, Outlook and Conclusion

Hyperspectral imaging represents a significant advancement in plastic surgery, offering a still cost-intensive, non-invasive, objective means of assessing tissue viability, guiding surgical decisions, and monitoring healing processes. However to become the gold standard in diagnostics and tissue evaluation

more research and trials with more acquired data and more included patients are of utmost importance. Also the accessibility of HSI acquired information for clinicians has to be enhanced since much useful data beyond the common parameters is only interpretable for skilled experts. As research and also the promising pairing of AI and HSI continues to evolve, Hyperspectral Imaging is likely to become also more cost-effective and thereby a valuable diagnostic tool in different fields of plastic surgery.

References

1. Parasca SV, Calin MA. Burn characterization using object-oriented hyperspectral image classification. J Biophotonics. 2022;15(11):e202200106.
2. Schulz T, Marotz J, Seider S, Langer S, Leuschner S, Siemers F. Burn depth assessment using hyperspectral imaging in a prospective single center study. Burns. 2022;48(5):1112-1119.
3. Wild T, Marotz J, Aljowder A, Siemers F. Burn Wound Dynamics Measured with Hyperspectral Imaging. Eur Burn J. 2025;6(1):7.
4. Kohler LH, Köhler H, Kohler S, Langer S, Nuwayhid R, Gockel I, et al. Hyperspectral Imaging (HSI) as a new diagnostic tool in free flap monitoring for soft tissue reconstruction: a proof of concept study. BMC Surg. 2021;21(1):222.
5. Schulz T, Nuwayhid R, Houschyar KS, Langer S, Kohler L. Diagnostical accuracy of hyperspectral imaging after free flap surgery. J Plast Surg Hand Surg. 2023;58:48-55.
6. Daeschlein G, Langner I, Wild T, von Podewils S, Sicher C, Kiefer T, et al. Hyperspectral imaging as a novel diagnostic tool in microcirculation of wounds. Clin Hemorheol Microcirc. 2017;67(3-4):467-474.
7. Saiko G, Lombardi P, Au Y, Queen D, Armstrong D, Harding K. Hyperspectral imaging in wound care: A systematic review. Int Wound J. 2020;17(6):1840-1856.
8. Vyas S, Banerjee A, Burlina P. Estimating physiological skin parameters from hyperspectral signatures. J Biomed Opt. 2013;18(5):57008.

Citation of this Article

Wild T, Besch JP, Marotz J and Buschmann I. About the Role and Current Impact of Hyperspectral Imaging in Plastic Surgery - A Brief Abstract. Mega J Case Rep. 2025;8(7):2001-2004.

Copyright