Diaspective Vision GmbH

TIVITA® Hyperspectral Camera System

Abstracts

Inhaltsverzeichnis:

Tissue characterization

Hyperspectral imaging of the degradation of meat and comparison with necrotic tissue in human wounds

(https://doi.org/10.1255/jsi.2019.a9)

Holmer A, Hornberger C, Wild T, Siemers F

2019

Journal of Spectral Imaging

The objective evaluation of scattering tissue and the discrimination of tissue types is an issue that cannot be solved with colour cameras and image processing alone in many cases. Examples can be found in the determination of freshness and ageing of meat, and the discrimination of tissue types in food technology. In medical applications, tissue discrimination is also an issue, e.g. in wound diagnostics. A novel hyperspectral imaging setup with powerful signal analysis algorithms is presented which is capable of addressing these topics. The spectral approach allows the chemical analysis of material and tissues and the measurement of their temporal change. We present a method of hyperspectral imaging in the visible-near infrared range which allows both the separation and spatial allocation of different tissue types in a sample, as well as the temporal changes of the tissue as an effect of ageing. To prove the capability of the method, the ageing of meat (slices of pork) was measured and, as a medical example, the application of the hyperspectral imaging setup for the recording of wound tissue is presented. The method shows the ability to discriminate the different tissue components of pork meat, and the ageing of the meat is observable as changes in spectral features. An additional result of our study is the fact that some spectral features, which seem to be typical for the ageing of the meat, are similar to those observed in the necrotic tissue from wound diagnostics in medicine.

Feedforward Artificial Neural Network-Based Colorectal Cancer Detection Using Hyperspectral Imaging: A Step towards Automatic Optical Biopsy

(DOI: 10.3390/cancers13050967)

Jansen-Winkeln B, Barberio M, Chalopin C, Schierle K, Diana M, Köhler H, Gockel I, Maktabi M

2021

Cancers

Simple Summary

Detection of colorectal carcinoma is performed visually by investigators and is confirmed pathologically. With hyperspectral imaging, an expanded spectral range of optical information is now available for analysis. The acquired recordings were analyzed with a neural network, and it was possible to differentiate tumor from healthy mucosa in colorectal carcinoma by automatic classification with high reliability. Classification and visualization were performed based on a four-layer perceptron neural network. Based on a neural network, the classification of CA or AD resulted in a sensitivity of 86% and a specificity of 95%, by means of leave-one-patient-out cross-validation. Additionally, significant differences in terms of perfusion parameters (e.g., oxygen saturation) related to tumor staging and neoadjuvant therapy were observed. This is a step towards optical biopsy.

Abstract

Currently, colorectal cancer (CRC) is mainly identified via a visual assessment during colonoscopy, increasingly used artificial intelligence algorithms, or surgery. Subsequently, CRC is confirmed through a histopathological examination by a pathologist. Hyperspectral imaging (HSI), a non-invasive optical imaging technology, has shown promising results in the medical field. In the current study, we combined HSI with several artificial intelligence algorithms to discriminate CRC. Between July 2019 and May 2020, 54 consecutive patients undergoing colorectal resections for CRC were included. The tumor was imaged from the mucosal side with a hyperspectral camera. The image annotations were classified into three groups (cancer, CA; adenomatous margin around the central tumor, AD; and healthy mucosa, HM). Classification and visualization were performed based on a four-layer perceptron neural network. Based on a neural network, the classification of CA or AD resulted in a sensitivity of 86% and a specificity of 95%, by means of leave-one-patient-out cross-validation. Additionally, significant differences in terms of perfusion parameters (e.g., oxygen saturation) related to tumor staging and neoadjuvant therapy were observed. Hyperspectral imaging combined with automatic classification can be used to differentiate between CRC and healthy mucosa. Additionally, the biological changes induced by chemotherapy to the tissue are detectable with HSI.

Tumor detection and treatment

Tumor cytotoxicity and immunogenicity of a novel V-jet neon plasma source compared to the kINPen

(DOI: 10.1038/s41598-020-80512-w)

Miebach L, Freund E, Horn S, Niessner F, Sagwal SK, von Woedtke T, Emmert S, Weltmann KD, Clemen R, Schmidt A, Gerling T, Bekeschus S

2021

Scientific Reports

Recent research indicated the potential of cold physical plasma in cancer therapy. The plethora of plasma-derived reactive oxygen and nitrogen species (ROS/RNS) mediate diverse antitumor effects after eliciting oxidative stress in cancer cells. We aimed at exploiting this principle using a newly designed dual-jet neon plasma source (Vjet) to treat colorectal cancer cells. A treatment time-dependent ROS/RNS generation induced oxidation, growth retardation, and cell death within 3D tumor spheroids were found. In TUM-CAM, a semi in vivo model, the Vjet markedly reduced vascularized tumors' growth, but an increase of tumor cell immunogenicity or uptake by dendritic cells was not observed. By comparison, the argon-driven single jet kINPen, known to mediate anticancer effects in vitro, in vivo, and in patients, generated less ROS/RNS and terminal cell death in spheroids. In the TUM-CAM model, however, the kINPen was equivalently effective and induced a stronger expression of immunogenic cancer cell death (ICD) markers, leading to increased phagocytosis of kINPen but not Vjet plasma-treated tumor cells by dendritic cells. Moreover, the Vjet was characterized according to the requirements of the DIN-SPEC 91315. Our results highlight the plasma device-specific action on cancer cells for evaluating optimal discharges for plasma cancer treatment.

Wound assessment/treatment

Detecting Bacteria on Wounds with Hyperspectral Imaging in Fluorescence Mode

(DOI: 10.1515/cdbme-2020-3067)

Herrmann B H, Daeschlein G, von Podewils S, Sicher C, Kuhn J, Masur K, Meister M, Wahl P, Hornberger C

2020

Current Directions in Biomedical Engineering

Abstract:

Chronic non-healing wounds represent an increasing problem. In order to enable physicians and nurses to make evidence based decisions on wound treatment, the professional societies call for supporting tools to be offered to physicians. Oxygen supply, bacteria colonization and other parameters influence the healing process. So far, these parameters cannot be monitored in an objective and routinely manner. Existing methods like the microbiological analysis of wound swabs, mean a great deal of effort and partly a long delay.

In this paper 42 fluorescence images from 42 patients with diabetic foot ulcer, recorded with a hyperspectral imaging system (TIVITA®), converted for fluorescence imaging, were analysed. Beside the fluorescence images, information about the bacterial colonization is available from microbiological analysis of wound swabs. After preprocessing, principal component analysis, PCA, is used for data analysis with a 405 nm excitation wavelength, the emission wavelength range 510 – 745 nm is used for analysis.

After dividing the data into a training and a test dataset it could be shown, that bacteria are detectable in the wound area. A quantification in bacterial colonization counts (BCC) was not in the focus of the research in this study stage.

Hyperspectral imaging in wound care: A systematic review

(DOI: 10.1111/iwj.13474)

Saiko G, Lombardi P, Au Y, Queen D, Armstrong D, Harding K

2020

International Wound Journal

Multispectral and hyperspectral imaging (HSI) are emerging imaging techniques with the potential to transform the way patients with wounds are cared for, but it is not clear whether current systems are capable of delivering realtime tissue characterisation and treatment guidance. We conducted a systematic review of HSI systems that have been assessed in patients, published over the past 32 years. We analysed 140 studies, including 10 different HSI systems. Current in vivo HSI systems generate a tissue oxygenation map. Tissue oxygenation measurements may help to predict those patients at risk of wound formation or delayed healing. No safety concerns were reported in any studies. A small number of studies have demonstrated the capabilities of in vivo label-free HSI, but further work is needed to fully integrate it into the current clinical workflow for different wound aetiologies. As an emerging imaging modality for medical applications, HSI offers great potential for non-invasive disease diagnosis and guidance when treating patients with both acute and chronic wounds.

Wound assessment/treatment

Hyperspectral Imaging of Wounds Reveals Augmented Tissue Oxygenation Following Cold Physical Plasma Treatment in Vivo

(DOI: 10.1109/TRPMS.2020.3009913)

Schmidt A, Niessner F, von Woedtke T, Bekeschus S

2020

IEEE Transactions on Radiation and Plasma Medical Sciences

Efficient vascularization of skin tissue supports wound healing in response to injury. This includes elevated blood circulation, tissue oxygenation, and perfusion. Cold physical plasma promotes wound healing in animal models and humans. Physical plasmas are multicomponent systems that generate several physicochemical effectors, such as ions, electrons, reactive oxygen and nitrogen species, and UV radiation. However, the consequences of plasma treatment on wound oxygenation and perfusion, vital processes to promote tissue regeneration, are largely unexplored. We used a novel hyperspectral imaging system and a murine dermal full-thickness wound model in combination with kINPen argon plasma jet treatment to address this question. Plasma treatment promoted tissue oxygenation in superficial as well as deep (6 mm) layers of wound tissue. In addition to perfusion changes, we found a wound healing stage-dependent shift of tissue hemoglobin and tissue water index during reactive species-driven wound healing. Contactless, fast monitoring of medical parameters in real-time using hyperspectral imaging revealed a plasma-supporting effect in wound healing together with precise information about biological surface-specific features.

Austrian natural ointment (Theresienöl®) with a high potential in wound healing – a European Review

(DOI: 10.1016/j.wndm.2020.100191)

Strashilov S, Slavchev S, Aljowder A, Vasileva P, Postelnicu-Gherasim S, Kostov S, Yordanov A

2020

Wound Medicine

Background:

The use of Theresienöl® (T.O.) a traditional Austrian natural product has been traced back to 1350. Medical wound care has always been a major concern and problem for people, especially in the Middle Ages. Even the smallest injuries or open wounds to become fatal due to poor hygienic conditions. Access to natural fats and vegetable ingredients made it possible to create a unique ointment named Theresienöl® which successfully treated multiple skin injuries including wounds, burns and scars.

Methods:

1.354 patients suffering of therapy-refractory skin injuries treated with T.O. within 38 centers between 2004 – 2020 in a cohort study. These were used for this review. Patients were divided by clinical criteria based on application duration and daily rate of reapplication strictly individualized depending on the degree of damage and efficiency results depending on the duration of the problem and the presence of chronic concomitant diseases. With a simplified application process a fine film of 2 drops/1 cm of the product (Depending on the vehicle of choice) over the wound or the affected areas, with a waiting time until partial absorption takes place followed by the dressing. It can be applied directly over the wound or over sterile bandages. The Primary endpoints were pain reduction, patient satisfaction both physically and aesthetically. Additionally we performed dermatological testing for irritation and allergy potential and rule out further side effects.

Results

After further evaluation of the 1.354 cases, statistically it showed an averaged of 89 % improvement rate in inflammation, an 88 % reduction rate in pruritus, 87 % of improved epithelisation, 93 % in patient benefit, and 91 % show improvement in wound closure. The Visual Analogue Scale of pain started at 829, a marked reduction was noted in the first 24 h with an average of 2,41. followed by a stable slow reduction of 173 on the 7th day.

Conclusion:

Treatment of Therapy-Refractory skin injuries including burns, scars, acute in addition to chronic wounds with T.O., witch is nearly 700 years old has shown for the first time exceptional results in an outpatient setting and was successful in alleviating inflammation, pain, itching and discomfort associated with wound care, thus providing an optimal opportunity for the wound to heal sufficiently and quickly without reported side effects.

Long-term Risk Assessment for Medical Application of Cold Atmospheric Pressure Plasma

(DOI: 10.3390/diagnostics10040210)

Rutkowski R, Daeschlein G, von Woedtke T, Smeets R, Gosau M, Metelmann H R

2020

Diagnostics

Despite increasing knowledge gained based on multidisciplinary research, plasma medicine still raises various questions regarding specific effects as well as potential risks. With regard to significant statements about in vivo applicability that cannot be prognosticated exclusively based on in vitro data, there is still a deficit of clinical data.

This study included a clinical follow-up of five probands who had participated five years previously in a study on the influence of cold atmospheric pressure plasma (CAP) on the wound healing of CO_2 laser-induced skin lesions. The follow-up included a complex imaging diagnostic involving dermatoscopy, confocal laser scanning microscopy (CLSM) and hyperspectral imaging (HSI). Hyperspectral analysis showed no relevant microcirculatory differences between plasma-treated and non-plasma-treated areas.

In summary of all the findings, no malignant changes, inflammatory reactions or pathological changes in cell architecture could be detected in the plasma-treated areas. These unique in vivo long-term data contribute to a further increase in knowledge about important safety aspects in regenerative plasma medicine. However, to confirm these findings and secure indication-specific dose recommendations, further clinical studies are required.

Plasmamedizin für chronische und akute Wunden: Sicher und effektiv

(DOI: ./.)

Emmert S, Fischer T, Bernhardt T, Borchardt T, Viöl W, Wahl P, Wandke D, Metelmann H, Masur K, Bekeschus S, von Woedtke T, Weltmann K D, Boeckmann L

2019

Chirurgische Allgemeine Zeitung

Wunden stellen eine äußerst heterogene Erkrankungsgruppe dar. Die häufigsten Ursachen von chronischen Hautwunden bestehen in venösen und/oder arteriellen Durchblutungsstörungen, Diabetes mellitus oder konstantem Druck. Die moderne Wundbehandlung besteht im Debridement, der oberflächlichen Keimreduktion, der Anlage von modernen Wundverbänden, die die Wunde feucht aber dennoch atmungsaktiv halten, sowie der Anlage von Kompressionsverbänden.

Die Anwendung von kaltem Atmosphärendruckplasma (Plasmamedizin) stellt dabei eine sehr innovative Behandlungsergänzung dar, da sie gleich mehrere Wirkprinzipien in einer Behandlungsanwendung vereint. Kaltes Atmosphärendruckplasma (KAP) beinhaltet viele aktive Komponenten, wie geladene Teilchen, UV-Strahlung, reaktive Gasspezies, Temperatur und Stromfluss. Diese wirken synergistisch. Eine Reihe klinischer Studien konnte bereits bakterizide, anti-inflammatorische und antiekzematöse Effekte von KAP aufzeigen. Im Bereich der Dermatologie fördert KAP vor allem die Wundheilung und beschleunigt regenerative Prozesse, lindert aber auch Juckreiz, Schmerz und moduliert die Hautbarriere.

Die internationale Studienlage und unsere eigenen Arbeiten zeigen, dass die Plasmaanwendung sicher, wirksam und einfach anwendbar ist.

Wound assessment

Hyperspectral imaging in perfusion and wound diagnostics - methods and algorithms for the determination of tissue parameters

(DOI: 10.1515/bmt-2017-0155)

Holmer A, Marotz J, Wahl P, Dau M, Kämmerer P

2018

Biomedical Engineering / Biomedizinische Technik

Blood perfusion is the supply of tissue with blood, and oxygen is a key factor in the field of minor and major wound healing. Reduced perfusion of a wound bed or transplant often causes various complications. Reliable methods for an objective evaluation of perfusion status are still lacking, and insufficient perfusion may remain undiscovered, resulting in chronic processes and failing transplants.

Hyperspectral imaging (HSI) represents a novel method with increasing importance for clinical practice. Therefore, methods, software and algorithms for a new HSI system are presented which can be used to observe tissue oxygenation and other parameters that are of importance in supervising healing processes. This could offer an improved insight into wound perfusion allowing timely intervention.

Wound assessment

Hyperspectral imaging: innovative diagnostics to visualize hemodynamic effects of cold plasma in wound therapy

(DOI: 10.1515/bmt-2017-0085)

Daeschlein G, Rutkowski R, Lutze S, v. Podewils S, Sicher C, Wild T, Metelmann H R, v. Woedkte T, Jünger M

2018

Biomedical Engineering / Biomedizinische Technik

An important clinical potential of cold atmospheric plasma (CAP) lies in tumor and wound treatment, whereby the last-mentioned is well-referenced already. However, the underlying mechanisms of improved wound healing have not been sufficiently clarified yet, in particular the influence of CAP on microcirculation.

Hyperspectral imaging (HSI) enables the visualization of microcirculation of large tissue areas, thus this technique seems to be a candidate to examine CAP effects on perfusion and oxygen saturation in wounds. During clinical wound management, one chronic wound caused by peripheral arterial occlusive disease and one acute wound after surgical removal of cervical lymph nodes were examined using HSI before and after CAP treatment. HSI was able to demonstrate CAP effects on microcirculation showing a relevant increase of superficial and deeper cutaneous oxygen saturation together with elevated hemoglobin concentration in treated and also surrounding wound area.

For the first time, it was shown that CAP improves the superficial and deeper oxygenation and hemoglobin perfusion in and around the treated area of acute and chronic wounds. This effect may contribute to healing support by CAP in wounds. HSI seems suitable for evaluating and monitoring CAP effects in clinical settings.

Hyperspectral imaging of tissue perfusion and oxygenation in wounds: assessing the impact of a micro capillary dressing

(DOI: 10.12968/jowc.2018.27.1.38)

Wild T, Becker M, Winter J, Schuschenk N, Daeschlein G, Siemers F

2018

Journal of Wound Care

Objective:

Experimental tests of non-invasive multi- or hyperspectral imaging (HSI) systems reveal the high potential of support for medical diagnostic purposes and scientific biomedical analysis. Until now, the use of HSI technologies for medical applications was limited by complex and overly sophisticated systems. We present a new and compact HSI-camera that could be used in normal clinical practice.

Method:

We assessed the use of the HSI system on the hands of 10 healthy volunteers, looking at control parameters, and those following venous occlusion, arterial occlusion and reperfusion, including tissue oxygenation, tissue hemoglobin index, perfusion in 4–6mm depth=near infrared spectroscopy (NIR), and tissue water index. Pseudo colours used ranged from 0% (blue) to 100% (red). We also assessed differences in the wounds of three patients.

Results:

The results show good potential in all parameters in the healthy volunteers, which had high conformity with validated reference oximetry measurements. In three wounds, different levels of oxygenation were identified in the wound area, although interpretation of these results is complex. In Cases 2 and 3, following the application of a micro capillary dressing, improvements were seen in perfusion and reduction of the tissue water index (TWI).

Conclusion:

The camera system proved to be quick, flexible and yielded data with high spatial and spectral resolution. These data will be used to perform a power analysis for a randomised controlled study.

Detecting signatures in hyperspectral image data of wounds: a compound model of self-organizing map and least square fitting

(DOI: 10.1515/cdbme-2018-0100)

Mohammed R, Schäle D, Emmert S, Hornberger C

2018

Current Directions in Biomedical Engineering

The purpose of this study is to develop a method to discriminate spectral signatures in wound tissue.

We have collected a training set of the intensity of the remitted light for different types of wound tissue from different patients using a TIVITA™ tissue camera. We used a neural network technique (self-organizing map) to group areas with the same spectral properties together. The results of this work indicates that neural network models are capable of finding clusters of closely related hyperspectral signatures in wound tissue, and thus can be used as a powerful tool to reach the anticipated classification.

Moreover, we used a least square method to fit literature spectra (i.e. oxygenated haemoglobin (O_2 Hb), deoxygenated hemoglobin (HHb), water and fat) to the learned spectral classes. This procedure enables us to label each spectral class with the corresponding absorbance properties for the different absorbance of interest (i.e. O_2 Hb, HHb, water and fat). The calculated parameters of a testing set were consistent with the expected behaviour and show a good agreement with the results of a second algorithm which is used in the TIVITA™ tissue camera.

Hyperspectral imaging as a novel diagnostic tool in microcirculation of wounds

(DOI: 10.3233/CH-179228)

Daeschlein G, Langner I, Wild T, von Podewils S, Sicher C, Kiefer T, Jünger M

2017

Clinical Hemorheology and Microcirculation

Methods:

HSI technology uses imaging spectroscopic analysis in visual and near infrared spectrum to get information on imaged tissue in less than 10 s. Tissue is radiated by broad spectrum light and the following parameters are calculated from remitted spectra: the grade of oxygenation and the volume proportion of hemoglobin (in superficial and also deeper (8 mm) tissues). The calculated data comprise the "Tissue hemoglobin oxygen saturation" (StO_2) as percental oxygenation index to assess superficial perfusion (VIS-spectrum), the "Near infrared perfusion" (NIR) to assess deeper perfusion (near infrared spectrum) and the "Tissue hemoglobin index" (THI) to measure the percental volume of hemoglobin of surface perfusion (VIS-spectrum). The measurements of these parameters are calculated as false color-coded perfusion results on screen. We investigated different kind of wounds (combustion, infection, ulcer wounds, wounds in immune disorders, trauma wounds) determining superficial and deeper oxygen saturation, hemoglobin distribution and water content using hyperspectral imaging with TIVITA™ Tissue system.

Results:

Hyperspectral Imaging allowed easy real time determination and visualization of hemodynamically relevant parameters- superficial and deeper oxygen saturation, total hemoglobin and tissue water content. In the patient with scleroderma, acral lesions with decreased perfusion correlated well with necrotic skin aspects. HSI clearly revealed macroscopic conspicuous suture wounds after Dupuytren surgery, infected soft tissue wounds with strong inflammatory hyperemia, edema in burn injuries, spatial geometry of abscess formation and chronic ulcer wounds. All measurements influenced further surveillance decisions. Hyperspectral imaging seems suitable for routine diagnostics and monitoring of skin and soft tissue lesions like acute and chronic wounds. It allows surveillance of postoperative suture wounds and burn wounds. Special indications may be transplant surveillance and monitoring of therapeutical interventions.

First results of a new hyperspectral camera system for chemical based wound analysis

(DOI: 10.1016/j.wndm.2015.11.003)

Marotz J, Siafliakis A, Holmer A, Kulcke A, Siemers F

2015

Wound medicine

Hyperspectral imaging and near infrared spectroscopy (NIRS) for wound analysis have been used in many scientific studies with good results for the chemical analysis of wounds and have the potential to raise objective measurement and assessment of wounds to a new level with considerable higher clinical informative value. Up to now, the clinical and scientific use of this technology has been hindered by the lack of a hyperspectral measurement system usable in clinical practice. We present the first hyperspectral camera for quick and robust acquisition of hyperspectral data in the combined VIS and NIR spectral range with high spectral and spatial resolution from wounds. First case studies and evaluations of chemometric parameters like the oxygenation of hemoglobin and perfusion quality are presented and exhibit the high quality and potential of this new wound measurement system.

3D-Perfusion analysis of burn wounds using Hyperspectral Imaging

(DOI: 10.1016/j.burns.2020.06.001)

Marotz J, Schulz T, Seider S, Cruz D, Aljowder A, Promny D, Daeschlein G, Wild T, Siemers F

2020

Burns

Background

Determination of the depth of burn wounds is still a challenge in clinical practise and fundamental for an optimal treatment. Hyperspectral Imaging (HSI) has a high potential to be established as a new contact-free measuring method in medicine. From hyperspectral spectra 3D-perfusion parameters can be estimated and the microcirculatory of burn wounds over the first 72 hours after thermal injury can be objectively described.

Methods

We used a hyperspectral imaging camera and extended data processing methods to calculate 3D-perfusion parameters of burn wounds from adult patients. The data processing results in the estimation of perfusion parameters like volume fraction and oxygenation of haemoglobin for 6 different layers of the injured skin. The parameters are presented as depth profiles. We analysed and compared measurements of wounds of different degrees of damage and present the methodology and preliminary results.

Results

The depth profiles of the perfusion parameters show characteristic features and differences depending on the degree of damage. With Hyperspectral Imaging and the advanced data processing the perfusion characteristics of burn wounds can be visualized in more detail. Based on the analysis of this perfusion characteristics, a new and better reliable classification of burn degrees can be developed supporting the surgeon in the early selection of the optimal treatment.

Objektive Tiefenbestimmung von Verbrennungen der Hand

(DOI: 10.1055/a-0991-7869)

Promny D, Billner M, Reichert B

2019

HaMiPla – Handchirurgie, Mikrochirurgie, plastische Chirurgie

The depth assessment of thermal wounds is subject to many variables. Therefore, technical systems are increasingly being used to determine severity. Particularly hand burns can have clinically relevant consequences in terms of function and aesthetic appearance. Hence, a secure assessment for an adequate treatment is necessary.

Technical analyzes such as Hyperspectral Imaging, Laser-Doppler-Imaging or Laser-Speckle-Imaging are intended to simplify and objectify the examination by helping to determine the necessary depth of necrectomy and thus to define the skin transplantation area. Furthermore, the diverse technical devices are to improve the functional result, reduce the severity of scarring and cosmetic complaints, and facilitate the evaluation of inexperienced personnel in the field of burn medicine.

Therefore, various technical approaches have been pursued, which are largely based on optical principles. The respective devices are not yet used in the standard diagnosis of burn wounds.

In future studies, it will be necessary to determine an algorithm for the measurement intervals based on the wound dynamics and to evaluate, which methodology is superior to the specificity and sensitivity.

Tiefenbestimmung von Verbrennungswunden durch Hyperspektralanalyse

(DOI: ./.)

Promny D, Aich J, Jaehn T, Reichert B B

2018

Plastische Chirurgie

Die Evaluation von Verbrennungswunden ist eine komplexe Untersuchung. Im Vordergrund steht unverändert die klinische und taktile Untersuchung. Die konventionelle histologische Analyse gilt zwar weiterhin als Goldstandard zur Evaluation der Verbrennungstiefe, ist jedoch aufgrund ihrer Invasivität und wegen des Zeitaufwandes für eine akute Entscheidungsfindung nicht verwertbar. Zudem ist die korrekte klinische Einschätzung oftmals fehlerbehaftet: In unterschiedlichen Studien zeigte sich, dass die Sensitivität auch bei erfahrenen Verbrennungschirurgen lediglich bei etwa 70 Prozent liegt.

Die zuverlässige und frühzeitige Einschätzung des Schädigungsgrades bzw. des noch vorhandenen Heilungspotentials der Verbrennungswunde ist jedoch wesentliche Voraussetzung für eine angemessene Therapieentscheidung. Aktuell werden unterschiedliche bildgebende Techniken zur Bewertung der Schädigungstiefe von Verbrennungen angewandt. Das modernste Verfahren nutzt das sog. Hyperspectral Imaging (HI).

Im Idealfall soll durch den Einsatz dieser Spektralkameras nicht nur eine Objektivierung der Auswertung möglich sein, sondern es können zudem auch tiefere Wundschichten beurteilt werden, so dass frühzeitig eine suffiziente chirurgische Therapie eingeleitet werden kann.

Es gilt nun zu evaluieren, in welchem Maße diese Geräte in Zukunft die Einschätzung von Verbrennungstiefen erleichtern und objektivieren können.

Assessing flap perfusion after free tissue transfer using hyperspectral imaging (HSI)

(DOI: 10.1007/s00238-021-01784-7)

Schulz T, Leuschner S, Siemers F, Marotz J, Houschyar K, Corterier C C

2021

European Journal of Plastic Surgery

Background

Hyperspectral imaging (HSI) is a new device for monitoring microcirculation. The aim of this study is to describe hyperspectral imaging after free tissue.

Methods

We assessed 22 patients from our department who underwent hyperspectral imaging monitoring. Four parameters were measured: tissue oxygenation, tissue hemoglobin index, deep tissue near-infrared perfusion index, and water distribution. Measurements were taken from normally perfused flaps, areas of locally impaired perfusion, and complete flap malperfusion daily within the first 7 days. Statistical differences were determined using Student's t tests. Receiver operating characteristic curves were illustrating the reliability of each parameter.

Results

Ten free anterolateral thigh flaps and eight free latissimus dorsi flaps were included. One flap was subsequently lost. Of 184 total measurements, 119 were taken in normally perfused flap areas, 63 in areas of locally impaired perfusion due to partial flap necrosis, and 2 were taken of a flap without perfusion due to arterial occlusion. In the latter case, tissue oximetry and tissue hemoglobin index were 3% (normally perfused flaps 37.5±12.6% ($p<0.05$) and 23.7±19.4% ($p<0.05$), respectively), whereas for locally impaired perfusion tissue, hemoglobin index was raised to 76.8±19.9% ($p<0.05$) and tissue oximetry and deep tissue near-infrared perfusion index were reduced to 28.8±15.8% ($p<0.05$) and 24.0±16.9% ($p<0.05$), respectively. A tissue hemoglobin index of ≥ 53% had a sensitivity of 92% and a specificity of 93% for the detection of locally impaired perfusion. Other parameters were less reliable.

Conclusions

HSI is a useful tool for flap monitoring after microsurgical tissue transfer. It provided accurate information which correlated with clinical assessments and guided decision-making regarding revision because it can easily detect impaired flap perfusion due to arterial occlusion or venous stasis. It also defined locally impaired perfused tissue at the flap border.

Level of evidence: Level IV, diagnostic study

Hyperspektralimaging zum postoperativen Lappenmonitoring von lokoregionären Lappenplastiken

(DOI: 10.1055/a-1167-3089)

Schulz T, Marotz J, Stukenberg A, Reumuth G, Houschyar K S, Siemers F

2020

Handchir Mikrochir Plast Chir

Hintergrund:

Seit der Erstbeschreibung einer lokoregionären Lappenplastik zur Nasenrekonstruktion im 6. Jahrhundert v. Chr. durch den indischen Arzt Sushruta Samhita sind diese ein fester Bestandteil in der Wiederherstellungschirurgie geworden. Neben der konsequenten Weiterentwicklung chirurgischer Operationsmethoden wurden die zu Grunde liegenden physikalischen Messmethoden des Lappenmonitoring in den letzten Dekaden stetig weiterentwickelt. Das Hyperspektralimaging (HSI) stellt eine neue quantitative Messmethode zur Beurteilung der Gewebeperfusion dar.

Ziel:

Das Ziel dieser Arbeit ist die Evaluation des HSI als Monitoringverfahren nach lokoregionärer Defektdeckung.

Patienten und Methode:

Bei insgesamt 16 Patienten wurde nach gefäßgestieltem Gewebetransfer die Sauerstoffsättigung, der Hämoglobingehalt sowie der Wassergehalt von Haut, Monitorinsel und nekrotischen Lappenarealen am 1. bis 7. postoperativen Tag gemessen. Die erhobenen Daten wurden statistisch deskriptiv ausgewertet und grafisch ausgearbeitet.

Ergebnisse:

Das HSI zeigte einen erhöhten Hämoglobingehalt, eine Abnahme der Sauerstoffsättigung sowie des Wassergehaltes in den nekrotischen Lappenarealen im Vergleich zur vitalen Monitorinsel und zur gesunden Haut. Monitorinsel und vitale Hautareale wiesen eine nahezu identische Werteverteilung auf.

Schlussfolgerung:

HSI erlaubt die sichere, kontaktfreie und sofortige Bestimmung der Gewebeperfusion von transferierten Gewebearealen bei Patienten nach lokoregionärer Defektdeckung. Daher erscheint die Verwendung von HSI im Rahmen des postoperativen Lappenmonitorings sinnvoll.

Hyperspectral analysis for perioperative perfusion monitoring—a clinical feasibility study on free and pedicled flaps

(DOI: 10.1007/s00784-020-03382-6)

Thiem D G E, Frick R W, Goetze E, Gielisch M, Al-Nawas B, Kämmerer P W

2020

Clinical Oral Investigations

Objectives:

In reconstructive surgery, flap monitoring is crucial for early identification of perfusion problems. Using hyperspectral imaging (HSI), this clinical study aimed to develop a non-invasive, objective approach for perfusion monitoring of free and pedicled flaps.

Material and methods:

HSI of 22 free (FF) and 8 pedicled flaps (PF) in 30 patients was recorded over time. Parameters assessed were tissue oxygenation/superficial perfusion (0–1 mm) (StO_2 (0–100%)), near-infrared perfusion/deep perfusion (0–4 mm) (NIR (0–100)), distribution of haemoglobin (THI (0–100)), and water (TWI (0–100)). Measurements up to 72 h were correlated to clinical assessment.

Results:

Directly after flap inset, mean StO_2 was significantly higher in FF (70.3 ± 13.6%) compared with PF 56.2 ± 14.2% ($p = 0.05$), whereas NIR, THI, and TWI were similar (NIR_$p = 0.82$, THI_$p = 0.97$, TWI_$p = 0.27$). After 24 h, StO_2, NIR, THI, and TWI did not differ between FF and PF. After 48 h, StO_2, NIR, and TWI did not differ between FF and PF whereas THI was significantly increased in FF compared with PF($p = 0.001$). In three FF, perfusion decreased clinically and in HSI, 36(1), 40(2), 5(3), and 61(3) h after flap inset which was followed by prompt intervention.

Conclusions:

$StO_2 < 40\%$, NIR < 25/100, and THI < 40/100 indicated arterial occlusion, whereas venous problems revealed an increase of THI. In comparison with FF, perfusion parameters of PF were decreased after flap transfer but remained similar to FF later on.

Clinical relevance:

HSI provides objective and non-invasive perfusion monitoring after flap transplantation in accordance to the clinical situation. With HSI, signs of deterioration can be detected hours before clinical diagnosis.

Intraoperative imaging

Intraoperative Perfusion Assessment in Enhanced Reality Using Quantitative Optical Imaging: An Experimental Study in a Pancreatic Partial Ischemia Model

(DOI: 10.3390/diagnostics11010093)

Wakabayashi T, Barberio M, Urade T, Pop R, Seyller E, Pizzicannella M, Mascagni P, Charles AL, Abe Y, Geny B, Baiocchini A, Kitagawa Y, Marescaux J, Felli E, Diana M

2021

Diagnostics

To reduce the risk of pancreatic fistula after pancreatectomy, a satisfactory blood flow at the pancreatic stump is considered crucial. Our group has developed and validated a real-time computational imaging analysis of tissue perfusion, using fluorescence imaging, the fluorescence-based enhanced reality (FLER). Hyperspectral imaging (HSI) is another emerging technology, which provides tissue-specific spectral signatures, allowing for perfusion quantification. Both imaging modalities were employed to estimate perfusion in a porcine model of partial pancreatic ischemia. Perfusion quantification was assessed using the metrics of both imaging modalities (slope of the time to reach maximum fluorescence intensity and tissue oxygen saturation (StO2), for FLER and HSI, respectively). We found that the HSI-StO2 and the FLER slope were statistically correlated using the Spearman analysis ($R = 0.697$; $p = 0.013$). Local capillary lactate values were statistically correlated to the HSI-StO2 and to the FLER slope ($R = -0.88$; $p < 0.001$ and $R = -0.608$; $p = 0.0074$). HSI-based and FLER-based lactate prediction models had statistically similar predictive abilities ($p = 0.112$). Both modalities are promising to assess real-time pancreatic perfusion. Clinical translation in human pancreatic surgery is currently underway.

Intraoperative imaging

Hyperspectral Imagery for Assessing Laser-Induced Thermal State Change in Liver

(DOI: 10.3390/s21020643)

De Landro M, Espíritu García-Molina I, Barberio M, Felli E, Agnus V, Pizzicannella M, Diana M, Zappa E, Saccomandi P

2021

Sensors

This work presents the potential of hyperspectral imaging (HSI) to monitor the thermal outcome of laser ablation therapy used for minimally invasive tumor removal. Our main goal is the establishment of indicators of the thermal damage of living tissues, which can be used to assess the effect of the procedure. These indicators rely on the spectral variation of temperature-dependent tissue chromophores, i.e., oxyhemoglobin, deoxyhemoglobin, methemoglobin, and water. Laser treatment was performed at specific temperature thresholds (from 60 to 110 °C) on in-vivo animal liver and was assessed with a hyperspectral camera (500-995 nm) during and after the treatment. The indicators were extracted from the hyperspectral images after the following processing steps: the breathing motion compensation and the spectral and spatial filtering, the selection of spectral bands corresponding to specific tissue chromophores, and the analysis of the areas under the curves for each spectral band. Results show that properly combining spectral information related to deoxyhemoglobin, methemoglobin, lipids, and water allows for the segmenting of different zones of the laser-induced thermal damage. This preliminary investigation provides indicators for describing the thermal state of the liver, which can be employed in the future as clinical endpoints of the procedure outcome.

Intraoperative imaging

Demarcation Line Assessment in Anatomical Liver Resection: An Overview

(DOI: 10.1177/1553350620953651)

Felli E, Urade T, Al-Taher M, Felli E, Barberio M, Goffin L, Ettorre GM, Marescaux J, Pessaux P, Swanstrom L, Diana M

2020

Surgical Innovation

Anatomical liver resection (ALR) is the preferred oncological approach for the treatment of primary liver malignancies, such as hepatocellular carcinoma and intrahepatic cholangiocarcinoma. The demarcation line (DL) is formed by means of selective vascular occlusion and is used by surgeons to guide ALR. Emerging intraoperative technologies are playing a major role to enhance the surgeon's vision and ensure a precise oncologic surgery. In this article, a brief overview of modalities to assess the DL during ALRs is presented, from the established conventional techniques to future perspectives.

Intraoperative imaging

A Novel Technique to Improve Anastomotic Perfusion Prior to Esophageal Surgery: Hybrid Ischemic Preconditioning of the Stomach. Preclinical Efficacy Proof in a Porcine Survival Model

(DOI: 10.3390/cancers12102977)

Barberio M, Felli E, Pop R, Pizzicannella M, Geny B, Lindner V, Baiocchini A, Jansen-Winkeln B, Moulla Y, Agnus V, Marescaux J, Gockel I, Diana M

2020

Cancers

Simple Summary:

Esophagectomy has a high rate of anastomotic complications thought to be caused by poor perfusion of the gastric graft, which is used to restore the continuity of the gastrointestinal tract. Ischemic gastric preconditioning (IGP), performed by partially destroying preoperatively the gastric vessels either by means of interventional radiology or surgically, might improve the gastric conduit perfusion. Both approaches have downsides. The timing, extent and mechanism of IGP remain unclear. A novel hybrid IGP method combining the advantages of the endovascular and surgical approach was introduced in this study. IGP improves unequivocally the mucosal and serosal blood-flow at the gastric conduit fundus by triggering new vessels formation. The proposed timing and extent of IGP were efficacious and might be easily applied to humans. This novel minimally invasive IGP technique might reduce the anastomotic leak rate of patients undergoing esophagectomy, thus improving their overall oncological outcome.

Abstract:

Esophagectomy often presents anastomotic leaks (AL), due to tenuous perfusion of gastric conduit fundus (GCF). Hybrid (endovascular/surgical) ischemic gastric preconditioning (IGP), might improve GCF perfusion. Sixteen pigs undergoing IGP were randomized: (1) Max-IGP (n = 6): embolization of left gastric artery (LGA), right gastric artery (RGA), left gastroepiploic artery (LGEA), and laparoscopic division (LapD) of short gastric arteries (SGA); (2) Min-IGP (n = 5): LGA-embolization, SGA-LapD; (3) Sham (n = 5): angiography, laparoscopy. At day 21 gastric tubulation occurred and GCF perfusion was assessed as: (A) Serosal-tissue-oxygenation (StO2) by hyperspectral-imaging; (B) Serosal time-to-peak (TTP) by fluorescence-imaging; (C) Mucosal functional-capillary-density-area (FCD-A) index by confocal-laser-endomicroscopy. Local capillary lactates (LCL) were sampled. Neovascularization was assessed (histology/immunohistochemistry). Sham presented lower StO2 and FCD-A index (41 ± 10.6%; 0.03 ± 0.03 respectively) than min-IGP Cancers 2020, 12, 2977; doi:10.3390/cancers12102977 www.mdpi.com/journal/cancersCancers 2020, 12, 2977 2 of 17 (66.2 ± 10.2%, p-value = 0.004; 0.22 ± 0.02, p-value < 0.0001 respectively) and max-IGP (63.8 ± 9.4%, p-value = 0.006; 0.2 ± 0.02, p-value < 0.0001 respectively). Sham had higher LCL (9.6 ± 4.8 mL/mol) than min-IGP (4 ± 3.1, p-value = 0.04) and max-IGP (3.4 ± 1.5, p-value = 0.02). For StO2, FCD-A, LCL, max- and min-IGP did not differ. Sham had higher TTP (24.4 ± 4.9 s) than max-IGP (10 ± 1.5 s, p-value = 0.0008) and min-IGP (14 ± 1.7 s, non-significant). Max- and min-IGP did not differ. Neovascularization was confirmed in both IGP groups. Hybrid IGP improves GCF perfusion, potentially reducing post-esophagectomy AL. xx

Intraoperative imaging

Identification of cutaneous perforators for microvascular surgery using hyperspectral technique - A feasibility study on the anterolateral thigh

(DOI: 10.1016/j.jcms.2020.09.005)

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[18] Goetze E, Thiem D G E, Gielisch M W, Kämmerer P W

2020

Journal of Cranio-Maxillo-Facial Surgery

Aim of the study was to compare perforator vessel location using color-coded Doppler ultrasound and hyperspectral imaging in the area of the antero-lateral thigh. In a cross-sectional case-control study, the bilateral antero-lateral thigh region was examined for perforator vessel location via color-coded Doppler ultrasound (control) and hyperspectral imaging (test). For hyperspectral imaging, all measurements were conducted without cooling (T0) and after 1 (T1), 2 (T2) and 3 min (T3) of cooling. Additionally, in the reperfusion period after cooling, hyperspectral imaging was conducted at 1, 2 and 3 min (T4/T5/T6).

Results from color-coded Doppler ultrasound and hyperspectral imaging were matched at all time points (T0eT6). In total, 71/73 perforator vessel locations could be matched (sensitivity: 97%). Matching of color-coded Doppler ultrasound and hyperspectral imaging was significantly influenced by the cooling protocol and the highest matching values were seen at T3 (3 min cooling; 60 perforator vessels) and T4 (3 min cooling & 1 min reperfusion; 62 perforator vessels) without significant differences (sensitivity 98%; p ¼ 0.9). There were significant differences between T4 and T0, T1 (both p < 0.001), T5 (p ¼ 0.045) and T6 (p ¼ 0.012). For clinical proof of concept, a patient case using a free antero-lateral thigh flap for reconstruction of a facial defect after perforator vessel identification via color-coded Doppler ultrasound and hyperspectral imaging (3 min cooling & 1 min reperfusion) was carried out successfully.

In conclusion, hyperspectral imaging potentially offers an additional opportunity for non-invasive, userindependent perforator-site assessment if prior cooling of the site is conducted.

Intraoperative imaging

Comparison of spectral characteristics in human and pig biliary system with hyperspectral imaging (HSI)

(DOI: 10.1515/cdbme-2020-0012)

Cooney G S, Barberio M, Diana M, Sucher R, Chalopin C, Köhler H

2020

Current Directions in Biomedical Engineering

Injuries to the biliary tree during surgical, endoscopic or invasive radiological diagnostic or therapeutic procedures involving the pancreas, liver or organs of the upper gastrointestinal tract give rise to the need to develop a method for clear discrimination of biliary anatomy from surrounding tissue. Hyperspectral imaging (HSI) is an emerging optical technique in disease diagnosis and image-guided surgery with inherent advantages of being a non-contact, non-invasive, and non-ionizing technique. HSI can produce quantitative diagnostic information about tissue pathology, morphology, and chemical composition. HSI was applied in human liver transplantation and compared to porcine model operations to assess the capability of discriminating biliary anatomy from surrounding biological tissue. Absorbance spectra measured from bile ducts, gall bladder, and liver show a dependence on tissue composition and bile concentration, with agreement between human and porcine datasets. The bile pigment biliverdin and structural proteins collagen and elastin were identified as contributors to the bile duct and gall bladder absorbance spectra.

Hyperspectral Imaging (HSI) of Human Kidney Allografts

(DOI: ./.)

Sucher R, Wagner T, Köhler H, Sucher E, Guice H, Recknagel S, Lederer A, Hau H M, Rademacher S, Schneeberger S, Brandacher G, Gockel I, Seehofer D

2020

Annals of Surgery

Objective:

Aim of our study was to test a noninvasive HSI technique as an intraoperative real time assessment tool for deceased donor kidney quality and function in human kidney allotransplantation.

Summary of Background Data:

HSI is capable to deliver quantitative diagnostic information about tissue pathology, morphology, and composition, based on the spectral characteristics of the investigated tissue. Because tools for objective intraoperative graft viability and performance assessment are lacking, we applied this novel technique to human kidney transplantation.

Methods:

Hyperspectral images of distinct components of kidney allografts (parenchyma, ureter) were acquired 15 and 45 minutes after reperfusion and subsequently analyzed using specialized HSI acquisition software capable to compute oxygen saturation levels (StO2), near infrared perfusion indices (NIR), organ hemoglobin indices, and tissue water indices of explored tissues.

Results:

Seventeen kidney transplants were analyzed. Median recipient and donor age were 55 years. Cold ischemia time was 10.8 4.1 hours and anastomosis time was 35 7 minutes (mean standard deviation). Two patients (11.8%) developed delayed graft function (DGF). Cold ischemia time was significantly longer (18.6 1.6) in patients with DGF (P < 0.01). Kidneys with DGF furthermore displayed significant lower StO2 (P ¼ 0.02) and NIR perfusion indices, 15minutes after reperfusion (P < 0.01). Transplant ureters displayed a significant decrease of NIR perfusion with increased distance to the renal pelvis, identifying well and poor perfused segments.

Conclusion:

Intraoperative HSI is feasible and meaningful to predict DGF in renal allografts. Furthermore, it can be utilized for image guided surgery, providing information about tissue oxygenation, perfusion, hemoglobin concentration, and water concentration, hence allowing intraoperative viability assessment of the kidney parenchyma and the ureter.

Intraoperative imaging

Demarcation Line Assessment in Anatomical Liver Resection: An Overview

(DOI: 10.1177/1553350620953651)

Felli E, Urade T, Al-Taher M, Felli M, Barberio M, Goffin L, Ettorre G M, Marescaux J, Pessaux P, Swanstrom L, Diana M

2020

Surgical Innovation

Anatomical liver resection (ALR) is the preferred oncological approach for the treatment of primary liver malignancies, such as hepatocellular carcinoma and intrahepatic cholangiocarcinoma. The demarcation line (DL) is formed by means of selective vascular occlusion and is used by surgeons to guide ALR. Emerging intraoperative technologies are playing a major role to enhance the surgeon's vision and ensure a precise oncologic surgery. In this article, a brief overview of modalities to assess the DL during ALRs is presented, from the established conventional techniques to future perspectives.

Intraoperative imaging

Workflow and hardware for intraoperative hyperspectral data acquisition in neurosurgery

(DOI: 10.1515/bmt-2019-0333)

Mühle R, Ernst H, Sobottka S B, Morgenstern U

2020

Biomedical Engineering / Biomedizinische Technik

To prevent further brain tumour growth, malignant tissue should be removed as completely as possible in neurosurgical operations. Therefore, differentiation between tumour and brain tissue as well as detecting functional areas is very important.

Hyperspectral imaging (HSI) can be used to get spatial information about brain tissue types and characteristics in a quasi-continuous reflection spectrum. In this paper, workflow and some aspects of an adapted hardware system for intraoperative hyperspectral data acquisition in neurosurgery are discussed.

By comparing an intraoperative with a laboratory setup, the influences of the surgical microscope are made visible through the differences in illumination and a pixel- and wavelength-specific signal-to-noise ratio (SNR) calculation. Due to the significant differences in shape and wavelength-dependent intensity of light sources, it can be shown which kind of illumination is most suitable for the setups. Spectra between 550 and 1,000 nm are characterized of at least 40 dB SNR in laboratory and 25 dB in intraoperative setup in an area of the image relevant for evaluation.

A first validation of the intraoperative hyperspectral imaging hardware setup shows that all system parts and intraoperatively recorded data can be evaluated. Exemplarily, a classification map was generated that allows visualization of measured properties of raw data.

The results reveal that it is possible and beneficial to use HSI for wavelength-related intraoperative data acquisition in neurosurgery. There are still technical facts to optimize for raw data detection prior to adapting image processing algorithms to specify tissue quality and function.

Hyperspectral Imaging of the Carotid Artery Subject to Endarterectomy

(DOI: 10.1016/j.ejvs.2020.07.073)

Sucher R, Sucher E, Köhler H, Schönherr T, Gockel I, Branzan D

2020

European Journal of Vascular & Endovascular Surgery

With regard to vessel wall remodelling, the adventitia has received considerable attention in recent years.

The outermost layer of the vessel wall not only contains a heterogenous population of cells, but also an adrenergic nervous system, a lymphatic network, and a specialised microvasculature. By supplying blood and oxygen to the vessel wall, these microvascular vasa vasorum represent the highway for oxygen and nutrient supply to the media and intima.

Experimental and clinical studies have demonstrated that intimal, medial, and adventitial remodelling occurs in response to revascularisation procedures. Unfortunately, a substantial percentage of these interventions is hampered by the occurrence of restenosis.

Surgical spectral imaging

(DOI: 10.1016/j.media.2020.101699)

Clancy N T, Jones G, Maier-Hein L, Elson D S, Stoyanov C

2020

Medical Image Analysis

Recent technological developments have resulted in the availability of miniaturised spectral imaging sensors capable of operating in the multi- (MSI) and hyperspectral imaging (HSI) regimes. Simultaneous advances in image-processing techniques and artificial intelligence (AI), especially in machine learning and deep learning, have made these data-rich modalities highly attractive as a means of extracting biological information non-destructively. Surgery in particular is poised to benefit from this, as spectrally-resolved tissue optical properties can offer enhanced contrast as well as diagnostic and guidance information during interventions. This is particularly relevant for procedures where inherent contrast is low under standard white light visualisation.

This review summarises recent work in surgical spectral imaging (SSI) techniques, taken from Pubmed, Google Scholar and arXiv searches spanning the period 2013-2019. New hardware, optimised for use in both open and minimally-invasive surgery (MIS), is described, and recent commercial activity is summarised. Computational approaches to extract spectral information from conventional colour images are reviewed, as tip-mounted cameras become more commonplace in MIS. Model-based and machine learning methods of data analysis are discussed in addition to simulation, phantom and clinical validation experiments. A wide variety of surgical pilot studies are reported but it is apparent that further work is needed to quantify the clinical value of MSI/HSI. The current trend toward data-driven analysis emphasises the importance of widely-available, standardised spectral imaging datasets, which will aid understanding of variability across organs and patients, and drive clinical translation.

Intraoperative imaging

Hyperspektral-Imaging (HSI) – eine verlässliche Gewebedifferenzierung?

(DOI: 10.1055/a-1030-3232)

Gockel I, Jansen-Winkeln B, Sucher R, Rayes N, Thieme R, Moulla Y, Niebisch S, Rademacher S, Seehofer D, Schierle K, Bläker H, Neumuth T, Melzer A, Maktabi M, Köhler H, Chalopin C

2020

Zentralblatt für Chirurgie

Die Hyperspektral-Bildgebung (HSI) hat sich als „Next Generation Real Time Imaging“ in der Viszeralchirurgie bereits für die Perfusionsmessungen gastrointestinaler Anastomosen sowie der Leberdurchblutung zur Identifikation der Resektionsgrenze nach Gefäßokklusion bei der anatomischen Leberresektion bewährt. Als kontaktlose, noninvasive Methode mit einer intraoperativen Aufnahme- und Prozesszeit von nur wenigen Sekunden bietet sie Vorteile gegenüber der NIR-Fluoreszenz (NIR: Near-InfraRed) mit Indocyaningrün (ICG) und ist zudem quantifizier- und objektivierbar.

Ob die mittels HSI analysierten chemischen/spektroskopischen Eigenschaften des Gewebes auch eine verlässliche Gewebedifferenzierung zulassen und mit Machine-Learning-Verfahren/künstlicher Intelligenz (KI) zukünftig automatisch ausgewertet werden können, soll in diesem Beitrag anhand der aktuell vorliegenden Literatur diskutiert werden.

Intraoperative imaging

Hyperspectral image-based analysis of thermal damage in living liver undergoing laser ablation

(DOI: 10.1117/12.2555465)

De Landro M, Barberio M, Felli E, Agnus V, Pizzicannell M, Diana M, Saccomandi P

2020

Clinical Biophotonics

Laser ablation (LA) is a minimally invasive procedure based on light/tissue interaction aimed to induce a controlled tumor necrosis by increasing tissue temperature. Given the relationship between tissue damage and produced heat, LA needs a fine control of evolving thermal effects in order to evaluate and control procedure outcome.

This study relies on biomedical optics principles for non-invasive diagnostic tools development, and presents a contactless approach based on hyperspectral imaging (HSI) to monitor thermal damage during *in vivo* porcine LA. By collecting relative pixel-by-pixel reflectance/absorbance of a wide range

spectrum (500-1000nm), HSI can track molecular structure modifications caused by the thermos-ablative procedure. Indeed, these modifications alter tissue light scattering and absorption.

In order to investigate tissue spectrum change by increasing temperature, HSI was collected at fixed maximum temperatures (37, 60, 70, 80, 90, 100, 110 °C) and immediately after LA (1, 2, 3, 4, and 5 minutes). Tissue spectral response for two tests was analyzed also relying on the ablated area considered. Regions of Interest of different dimensions (16, 77, and 170 pixels) were placed in the images after applying a motion correction. Obtained spectra show noticeable variations once a specific temperature threshold has been reached (80-100 °C). Specifically, the measured absorbance variation for selected wavelengths (630, 760, 960nm, for methemoglobin, deoxyhemoglobin, and water respectively) confirms tissue optical behavior dependence with its thermal state.

This preliminary investigation discloses the potential of HSI measurement to characterize LA damage, encouraging future studies to standardize this novel technique.

Intraoperative imaging

Quantitative fluorescence angiography versus hyperspectral imagin to assess bowel ischemia: A comparative study in enhanced reality

(DOI: 10.1016/j.surg.2020.02.008)

Barberio M, Felli E, Seyller E, Longo F, Chand M, Gockel I, Geny B, Swanström L, Marescaux J, Agnus V, Diana M

2020

Surgery

Background

Fluorescence-based enhanced reality is a software that provides quantitative fluorescence angiography by computing the fluorescence intensity time-to-peak after intravenous indocyanine green. Hyperspectral imaging is a contrast-free, optical imaging modality which measures tissue oxygenation.

Methods

In 8 pigs, an ischemic bowel segment created by dividing the arcade branches was imaged using hyperspectral imaging and fluorescence-based enhanced reality. Tissue oxygenation values were acquired through a hyperspectral imaging system. Subsequently, fluorescence angiography was performed using a near-infrared laparoscopic camera after intravenous injection of 0.2 mg/kg of indocyanine green. The time-to-peak fluorescence signal was analyzed through a proprietary software to realize a perfusion map. This was overlaid onto real-time images to obtain fluorescence-based enhanced reality. Simultaneously, 9 adjacent regions of interest were selected and superimposed onto the real-time video, thereby obtaining hyperspectral-based enhanced reality. Fluorescence-based enhanced reality and hyperspectral-based enhanced reality were superimposed allowing a comparison of both imaging modalities. Local capillary lactate levels were sampled at the regions of interest. Two prediction models using the local capillary lactate levels were extrapolated based on both imaging systems.

Results

For all regions of interest, the mean local capillary lactate levels were 4.67 ± 4.34 mmol/L, the mean tissue oxygenation was 45.9 ± 18.9%, and the mean time-to-peak was 10 ± 9.4 seconds. Pearson's test between fluorescence-based enhanced reality-time-to-peak and hyperspectral imaging-tissue oxygenation at the corresponding regions of interest gave an $R = -0.66$ ($P < .0001$). The hyperspectral imaging lactate prediction model proved more accurate than the fluorescence-based enhanced reality-based model ($P < .0001$).

Conclusion

Bowel perfusion was quantified using hyperspectral imaging and fluorescence angiography. Hyperspectral imaging yielded more accurate results than fluorescence angiography. Hyperspectral-based enhanced reality may prove to be a useful, contrast-free intraoperative tool to quantify bowel ischemia.

Digitalisierung und Ansätze künstlicher Intelligenz in der mikrovaskulär-rekonstruktiven Gesichtschirurgie

(DOI: 10.1007/s00104-019-01103-8)

Goetze E, Thiem D G E, Gielisch M, Al-Nawas B, Kämmerer P W

2020

Der Chirurg

Background

When using digitalization and artificial intelligence (AI), large amounts of data (big data) are produced, which can be processed by computers and used in the field of microvascular-reconstructive craniomaxillofacial surgery (CMFS).

Objective

The aim of this article is to summarize current applications of digitalized medicine and AI in microvascular reconstructive CMFS.

Material and methods

Review of frequent applications of digital medicine for microvascular CMFS reconstruction, focusing on digital planning, navigation, robotics and potential applications with AI.

Results

The broadest utilization of medical digitalization is in the virtual planning of microvascular transplants, individualized implants and template-guided reconstruction. Navigation is commonly used for ablative tumor surgery but less frequently in reconstructions. Robotics are mainly employed in the transoral approach for tumor surgery of the hypopharynx, whereas the use of AI is still limited even if possible applications would be automated virtual planning and monitoring systems.

Conclusion

The use of digitalized methods and AI are adjuncts to microvascular reconstruction. Automatization approaches and simplification of technologies will provide such applications to a broader clientele in the future; however, in CMFS, robotic-assisted resections and automated flap monitoring are not yet the standard of care.

Intraoperative Bildgebung und Visualisierung

(DOI: 10.1007/s00761-019-00695-4)

Maier-Hein L, Gockel I, Speidel S, Wendler T, Teber D, März K, Tizabi M, Nickel F, Navab N, Müller-Stich B

2020

Der Onkologe

Background

Surgical oncology is an important pillar of interdisciplinary cancer treatment. The intraoperative visualization of tumors and critical structures along with functional tissue parameters is an important basis for precise surgical treatment and thus for the optimization of patient outcome.

Objective

The aim of this article was to compile the latest technological developments with particular relevance to intraoperative imaging and visualization.

Methods

Medical and technical experts with experience in computer-assisted surgery identified four research areas with a high potential for sustainably improving surgical oncology: (1) functional imaging based on biophotonics, (2) multimodal data visualization through augmented reality, (3) reproducible imaging by means of robotics, and (4) context-aware visualization based on surgical data science.

Results

Recent publications exemplify the high potential of the four subject areas presented.

Conclusion

Future research should focus on optimizing robustness and integrability into the surgical workflow.

Hyperspectral imaging for thermal effect monitoring in *in vivo* liver during laser ablation

(DOI: 10.1109/EMBC.2019.8856487)

De Landro, M, Saccomandi P, Barberio M, Schena E, Marescaux M. J., Diana M

2019

41st Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC)

Thermal ablation is a minimally invasive technique used to induce a controlled necrosis of malignant cells by increasing the temperature in localized areas. This procedure needs an accurate and real-time monitoring of thermal effects to evaluate and control treatment outcome. In this work, a hyperspectral imaging (HSI) technique is proposed as a new and non-invasive method to monitor ablative therapy. HSI provides images of the target object in several spectral bands, hence the reflectance/absorbance spectrum for each pixel.

This paper presents a preliminary and original HSI-based analysis of the thermal state in the in vivo porcine liver undergoing laser ablation. In order to compare the spectral response between treated and untreated areas of the organ, proper Regions of Interest (ROIs) were chosen on the hyperspectral images; for each ROI, the absorbance variation for the selected wavelengths (i.e., 630, 760, and 960nm, for deoxyhemoglobin, methemoglobin, and water respectively) was assessed.

Results obtained during and after laser ablation show that the absorbance of the methemoglobin peaks increases up to 40% in the burned region with respect to the non-ablated one. Conversely, the relative change of deoxyhemoglobin and water peaks is less marked. Based on these results, absorbance threshold values were retrieved and used to visualize the ablation zone on the images.

This preliminary analysis suggests that a combination of the absorbance information is essential to achieve a more accurate identification of the ablation region. The results encourage further studies on the correlation between thermal effects and the spectral response of biological tissues undergoing thermal ablation, for final clinical use.

Hyperspectral Imaging (HSI) in anatomic left liver resection

(DOI: 10.1016/j.ijscr.2019.08.025)

Sucher R, Athanasios A, Köhler H, Wagner T, Brunotte M, Lederer A, Gockel I, Seehofer D

2019

International Journal of Surgery Case Reports

Introduction

Anatomic liver resection is based on the description of functional segments, which rely on the organs arterial and portal venous blood supply. Vascular inflow control of the left liver is performed by occlusion of the left hepatic artery (LHA) and left portal vein (LPV). Depending on the quality of the parenchyma a sharp demarcation line (Cantlie Line) between segments IV and V/VIII can hence be detected.

Material and Methods

TIVITA® is a novel contact free tool which facilitates non-invasive hyperspectral imaging (HSI) and near infrared spectroscopy (NIRS) for the assessment of tissue- oxygenation (StO_2) and perfusion (NIR Perfusion). We hypothesized that this imaging modality might be practicable to identify the future resection plane after left vascular inflow occlusion in anatomic liver resection.

Presentation of Case

TIVITA® is a viable tool for the identification of segments with reduced StO_2 (inflow occlusion: 0.23 ± 0.03 vs normal: 0.50 ± 0.06) and NIR Perfusion (inflow occlusion: 0.02 ± 0.04 vs normal: 0.47 ± 0.06) and allows for a visual differentiation of well oxygenated, perfused (green) and low oxygenated, poorly perfused (blue) liver tissue in a patient undergoing left hemihepatectomy for hepatocellular carcinoma.

Conclusion

Hyperspectral Imaging is an emerging optical technique with the potential to identify exact resection planes for anatomic liver resection based on the optically determined perfusion and oxygenation status of liver segments lined up for resection. This novel Hyperspectral Demarcation Technique (HSI DT) is non- contact, non-ionizing and non-invasive.

Intraoperative imaging

Hyperspectral Imaging of pig liver Ischemia: a proof of concept

(DOI: 10.3966/156104972019121802005)

Felli E, Barberio M, Urade T, Felli E, Seeliger B, Marescaux J, Diana M

2019

Show–Chwan Medical Journal

Liver ischemia is a process characterised by the decrease of oxygen pressure which leads to the production of Reactive Oxygen Species (ROS), Damage Associated Molecular Patterns (DAMPs), cytokines and chemokines. Once the blood flow is re-established, a massive recruitment of neutrophils induces hepatocyte death in a process called Ischemic Reperfusion Injury (IRI). This type of damage is a common cause of morbidity and mortality in surgical operations with prolonged ischemic time. Currently, there is not any available tool to predict IRI damage in real-time.

Hyperspectral imaging (HSI) is a non-invasive device able to quantify information in real time from the emitted electromagnetic spectrum of a specific surface. Here we show the ability of HSI to assess and discriminate between ischemic and non-ischemic liver after 15 min of portal vein and hepatic artery ligation. HSI analysis for StO2% and Near Infrared Perfusion Index showed a drastic reduction in both indices, from 42% to 20% and from 43% to 0% respectively. The ischemia detected by the HSI was confirmed by the systemic and local lactate analysis that showed an increase of 50% (from 1.8 to 3.6 mmol/l), and 76% (from 2.3 to 9.7 mmol/l).

HYPerspectral Enhanced Reality (HYPER): a physiology-based surgical guidance tool

(DOI: 10.1007/s00464-019-06959-9)

Barberio M, Longo F, Fiorillo C, Seeliger B, Mascagni P, Agnus, V, Lindner V, Geny B, Charles A L, Gockel I, Worreth M, Saadi A, Marescaux J, Diana M

2019

Surgical Endoscopy

Background

HSI is an optical technology allowing for a real-time, contrast-free snapshot of physiological tissue properties, including oxygenation. Hyperspectral imaging (HSI) has the potential to quantify the gastrointestinal perfusion intraoperatively. This experimental study evaluates the accuracy of HSI, in order to quantify bowel perfusion, and to obtain a superposition of the hyperspectral information onto real-time images.

Methods

In 6 pigs, 4 ischemic bowel loops were created (A, B, C, D) and imaged at set time points (from 5 to 360 min). A commercially available HSI system provided pseudo-color maps of the perfusion status (StO_2, Near-InfraRed perfusion) and the tissue water index. An ad hoc software was developed to superimpose HSI information onto the live video, creating the HYPerspectral-based Enhanced Reality (HYPER). Seven regions of interest (ROIs) were identified in each bowel loop according to StO_2 ranges, i.e., vascular (VASC proximal and distal), marginal vascular (MV proximal and distal), marginal ischemic (MI proximal and distal), and ischemic (ISCH). Local capillary lactates (LCL), reactive oxygen species (ROS), and histopathology were measured at the ROIs. A machine-learning-based prediction algorithm of LCL, based on the HSI-StO_2%, was trained in the 6 pigs and tested on 5 additional animals.

Results

HSI parameters (StO_2 and NIR) were congruent with LCL levels, ROS production, and histopathology damage scores at the ROIs discriminated by HYPER. The global mean error of LCL prediction was 1.18 ± 1.35 mmol/L. For StO2 values > 30%, the mean error was 0.3 ± 0.33.

Conclusions

HYPER imaging could precisely quantify the overtime perfusion changes in this bowel ischemia model.

Intraoperative imaging

New intraoperative imaging technologies: Innovating the surgeon's eye toward surgical precision

(DOI: 10.1002/jso.25148)

Mascagni P, Longo F, Barberio M, Seeliger B, Agnus V, Saccomandi P, Hostettler A, Marescaux J, Diana M

2018

Imaging is one of the pillars for the ongoing evolution of surgical oncology toward a precision paradigm. In the present overview, some established or emerging intraoperative imaging technologies are described in light of the vision and experience of our group in image-guided surgery, focusing on digestive surgical oncology.

Was gibt es Neues in der computerassistierten Chirurgie?

(DOI: ./.)

Chalopin C, Landgraf L, Melzer A, Neumuth T H, Oelze-Jafra S T, Salz P

2018

Was gibt es Neues in der Chirurgie? (Jahresband)

Der Computer hat wie kein anderes Medium unsere Welt verändert und ist aus dem täglichen Leben nicht mehr wegzudenken. Anders verhält es sich in der allgemeinen Chirurgie und im Operationssaal. Die dort verwendete Technologie ist bereits sehr fortschrittlich und computergesteuert, jedoch sind die einzelnen Geräte und Systeme in der Regel Insellösungen, die nicht in das System des Operationssaals integriert sind und einzeln bedient werden müssen.

Die Ziele der computerassistierten Chirurgie, wie diese mit der Gründung des ICCAS in Leipzig definiert wurden, beinhalten die Integration der Instrument-Komponenten und Subsysteme, welche für eine Operation notwendig sind. Zudem soll das Equipment zentral vom Chirurgen kontrolliert und gesteuert werden und das Gesamtsystem sich auf die jeweiligen Schritte und Phasen der Operation soweit wie möglich einstellen.

Neben den chirurgischen Systemen sind zunehmend die radiologischen bildgebenden Verfahren in die Operation mit einbezogen, z. B. Angiographieanlagen, CT oder MRT. Des Weiteren ist die intraoperative Bildgebung – speziell im mikroskopischen Bereich – auf dem Vormarsch mit dem Ziel, das Ergebnis von chirurgischen Eingriffen noch zu verbessern. Nicht-invasive und nicht-ionisierende Verfahren, die der Chirurg zudem alleine bedienen kann, sollen die Nutzung von Bildgebung sicherer für den Patienten und für das medizinische Personal gestalten. So werden z. B. mit Wärmebildkameras, Ultraschall und optischen Techniken wie OCT, RAMAN, Hyperspektralbildgebung und Photoakustik, dem Chirurgen mehr und mehr Daten aus den Geweben und Organen geliefert.

Eine weitere zukunftsweisende Komponente ist die Anbindung des Operationssystems an die klinischen Daten des Patienten, so dass diese in die chirurgischen Entscheidungsprozesse mit einbezogen werden können.

Hybridösophagektomie mit intraoperativem Hyperspektral-Imaging : Videobeitrag

(DOI: 10.1007/s00104-020-01139-1)

Moulla Y, Reifenrath M, Rehmet K, Niebisch S, Jansen-Winkeln B, Sucher R, Hoffmeister A, Kreuser N, Köhler H, Gockel I

2020

Der Chirurg

Abstract:

Die Technik der Hybridösophagektomie mit systematischer 2-Feld-Lymphadenektomie beim Ösophaguskarzinom zeigte in einer aktuell publizierten prospektiv-randomisierten Studie eine signifikante Reduktion der postoperativen Morbidität. In unserem Videobeitrag stellen wir das abdominothorakale Hybridvorgehen mit (1.) laparoskopischer Gastrolyse und ischämischer Konditionierung des Magens und (2.) zweizeitiger transthorakaler Ösophagektomie mit Magenhochzug, intrathorakaler Schlauchmagenbildung und Anastomosierung dar. Das intraoperative Hyperspektral-Imaging (HSI) während des thorakalen Teils der Operation dient der Identifikation der ideal perfundierten Anastomosenregion.

Semi-automatic decision-making process in histopathological specimens from Barrett's carcinoma patients using hyperspectral imaging (HSI)

(DOI: 10.1515/cdbme-2020-3066)

Maktabi M, Köhler H, Chalopin C, Neumuth T, Wichmann Y, Jansen-Winkeln B, Gockel I, Thieme R, Ahle H, Lorenz D, Bange M, Braun S

2020

Current Directions in Biomedical Engineering

Abstract:

Discrimination of malignant and non-malignant cells of histopathologic specimens is a key step in cancer diagnostics. Hyperspectral Imaging (HSI) allows the acquisition of spectra in the visual and near-infrared range (500-1000nm). HSI can support the identification and classification of cancer cells using machine learning algorithms. In this work, we tested four classification methods on histopathological slides of esophageal adenocarcinoma. The best results were achieved with a Multi-Layer Perceptron. Sensitivity and F1-Score values of 90% were obtained.

Hyperspektralimaging bei Ileoanalen-Pouch-Operationen

(DOI: 10.1055/s-0040-1716265)

Jansen-Winkeln B, Takoh JP, Köhler H, Gockel I

2020

Zeitschrift für Gastroenterologie

Einleitung

Die Ileoanale Pouch-Anlage nach Proktokolektomie bei Colitis ulcerosa oder familiärer adenomatöser Polyposis (FAP) ist eine herausfordernde Operation, gerade die Mobilisation des Pouches ins kleine Becken kann durch die Gefäße (Ileokolische Äste oder Mesenterica-superior Äste) kompliziert sein. Teilweise müssen diese Gefäße zur Längengewinnung durchtrennt werden. Dabei ist die gute Durchblutung des Pouches Voraussetzung für ein gutes Einheilen. Und ein gut verheilter Pouch ist die Voraussetzung für eine gute spätere Funktion.

Material und Methode

Mit der hyperspektral-Bildgebung (HSI) werden Wellenlängen zwischen 500 und 1000 nm zusätzlich zu dem sichtbaren Licht ausgewertet und anhand von spezifischen Reflexmustern können u.a. die Durchblutung und die Perfusion untersucht werden.

Wir haben 20 Patienten mit Pouchanlage in einem medianen Alter von 33 Jahren (16-62 Jahre) prospektiv untersucht und den Pouch vor Anastomosierung mit der HSI-Kamera analysiert. Die Perfusion wurde intraoperativ an 4 definierten Stellen des J-Pouches gemessen.

Ergebnisse

Die Perfusion in den gemessenen Abschnitten zeigte in allen Patienten eine gute Perfusion und Sauerstoffsättigungswerte von über 75%. Dabei ist bemerkenswert, dass der Scheitelpunkt eine breitere Streuung der Messparameter auswies als die proximalen und distalen Werte. Die Anstomosenregion wies eine signifikant geringere Perfusion auf, als die übrigen Messparameter. Der Gewebs-Wasser-Index zeigte sich bei den Re-Pouch-Operationen im Vergleich zu den Primär-OPs signifikant erhöht. Klinisch zeigten sich drei kleine postoperative Nahtdehiszenzen in der Re-Pouch-Gruppe, die mit EndoSponge behandelt werden konnten und ein kleiner intraoperativer Pouch-Einriss, der ebenso mittels primärer EndoSponge-Therapie komplikationslos ausheilte.

Schlussfolgerung

Die Pouch-Durchblutung war bei allen Operationen gut und so kam es bei den Primär-Operationen zu keiner postoperativen Insuffizienz der Ileo-Pouch-analen Anastomose. Die Re-Pouch-Operationen hatten hingegen eine Insuffizienzrate, die sich auch in der Literatur wiederfindet. Die HSI ist eine gute intraoperative Methode um den Pouch vor Anastomose zu überprüfen.

Quantitative serosal and mucosal optical imaging perfusion assessment in gastric conduits for esophageal surgery: an experimental study in enhanced reality

(DOI: 10.1007/s00464-020-08077-3)

Barberio M, Felli E, Pizzicannella M, Agnus V, Al-Taher M, Seyller E, Moulla Y, Jansen-Winkeln B, Gockel I, Marescaux J, Diana M

2020

Surgical Endoscopy

Introduction/objective

Gastric conduit (GC) is used for reconstruction after esophagectomy. Anastomotic leakage (AL) incidence remains high, given the extensive disruption of the gastric circulation. Currently, there is no reliable method to intraoperatively quantify gastric perfusion. Hyperspectral imaging (HSI) has shown its potential to quantify serosal StO_2. Confocal laser endomicroscopy (CLE) allows for automatic mucosal microcirculation quantification as functional capillary density area (FCD-A). The aim of this study was to quantify serosal and mucosal GC's microperfusion using HSI and CLE. Local capillary lactate (LCL) served as biomarker.

Methods

GC was formed in 5 pigs and serosal StO_2% was quantified at 3 regions of interest (ROI) using HSI: fundus (ROI-F), greater curvature (ROI-C), and pylorus (ROI-P). After intravenous injection of sodium-fluorescein (0.5 g), CLE-based mucosal microperfusion was assessed at the corresponding ROIs, and LCLs were quantified via a lactate analyzer.

Results

StO_2 and FCD-A at ROI-F (41 ± 10.6%, 3.3 ± 3.8, respectively) were significantly lower than ROI-C (68.2 ± 6.7%, p value: 0.005; 18.4 ± 7, p value: 0.01, respectively) and ROI-P (72 ± 10.4%, p value: 0.005; 15.7 ± 3.2 p value: 0.001). LCL value at ROI-F (9.6 ± 4.7 mmol/L) was significantly higher than at ROI-C (2.6 ± 1.2 mmol/L, p value: 0.04) and ROI-P (2.6 ± 1.3 mmol/L, p value: 0.04). No statistically significant difference was found in all metrics between ROI-C and ROI-P. StO_2 correlated with FCD-A (Pearson's r = 0.67). The LCL correlated negatively with both FCD-A (Spearman's r = - 0.74) and StO_2 (Spearman's r = - 0.54).

Conclusions

GC formation causes a drop in serosal and mucosal fundic perfusion. HSI and CLE correlate well and might become useful intraoperative tools.

Comparison of hyperspectral imaging and fluorescence angiography for the determination of the transection margin in colorectal resections—a comparative study

(DOI: 10.1007/s00384-020-03755-z)

Jansen-Winkeln B, Germann I, Köhler H, Mehdorn M, Maktabi M, Sucher R, Barberio M, Chalopin C, Diana M, Moulla Y, Gockel I

2020

International Journal of Colorectal Disease

Purpose

One relevant aspect for anastomotic leakage in colorectal surgery is blood perfusion of both ends of the anastomosis. The clinical evaluation of this issue is limited, but new methods like fluorescence angiography with indocyanine green or noninvasive and contactless hyperspectral imaging have evolved as objective parameters for perfusion evaluation.

Methods

In this prospective, non-randomized, open-label and two-arm study, fluorescence angiography and hyperspectral imaging were compared in 32 consecutive patients with each other and with the clinical assessment by the surgeon. After preparation of the bowel and determination of the surgical resection line, the tissue was evaluated with hyperspectral imaging for 5 min before and after cutting the marginal artery and assessed by 6 hyperspectral pictures followed by fluorescence angiography with indocyanine green.

Results

In 30 of 32 patients, the image data could be evaluated and compared. Both methods provided a comparable borderline between well-perfused and poorly perfused tissue ($p = 0.704$). In 15 cases, the surgical resection line was shifted to the central position due to the imaging. The border zone was sharper in fluorescence angiography and best assessed 31 s after injection. With hyperspectral imaging, the border zone was visualized wider and with more differences between proximal and distal border.

Conclusion

Hyperspectral imaging and fluorescence angiography provide similar results in determining the perfusion border. Both methods allow a good and safe visualization of the blood perfusion at the central resection margin to create a well-perfused anastomosis.

Hyperspectral evaluation of hepatic oxygenation in a model of total vs. arterial liver ischaemia

(DOI: 10.1038/s41598-020-72915-6)

Felli E, Al-Taher M, Collins T, Baiocchini A, Felli E, Barberio M, Ettorre G M, Mutter D, Lindner V, Hostettler A, Gioux S, Schuster C, Marescaux J, Diana M

2020

Scientific Reports

Liver ischaemia reperfusion injury (IRI) is a dreaded pathophysiological complication which may lead to an impaired liver function. The level of oxygen hypoperfusion affects the level of cellular damage during the reperfusion phase. Consequently, intraoperative localisation and quantification of oxygen impairment would help in the early detection of liver ischaemia. To date, there is no real time, non invasive, and intraoperative tool which can compute an organ oxygenation map, quantify and discriminate different types of vascular occlusions intraoperatively. Hyperspectral imaging (HSI) is a non invasive optical methodology which can quantify tissue oxygenation and which has recently been applied to the medical field. A hyperspectral camera detects the relative reflectance of a tissue in the range of 500 to 1000 nm, allowing the quantification of organic compounds such as oxygenated and deoxygenated haemoglobin at different depths. Here, we show the first comparative study of liver oxygenation by means of HSI quantification in a model of total vascular inflow occlusion (VIO) vs. hepatic artery occlusion (HAO), correlating optical properties with capillary lactate and histopathological evaluation. We found that liver HSI could discriminate between VIO and HAO. These results were confirmed via cross validation of HSI which detected and quantified intestinal congestion in VIO. A significant correlation between the near infrared spectra and capillary lactate was found ($r = -0.8645$, $p = 0.0003$ VIO, $r = -0.7113$, $p = 0.0120$ HAO). Finally, a statistically significant negative correlation was found between the histology score and the near infrared parameter index (NIR) ($r = -0.88$, $p = 0.004$). We infer that HSI, by predicting capillary lactates and the histopathological score, would be a suitable non invasive tool for intraoperative liver perfusion assessment.

Laparoscopic system for simultaneous high-resolution video and rapid hyperspectral imaging in the visible and near-infrared spectral range

(DOI: 10.1117/1.JBO.25.8.086004)

Köhler H, Kulcke A, Maktabi M, Moulla Y, Jansen-Winkeln B, Barberio M, Diana M, Gockel I, Neumuth T, Chalopin C

2020

SPIE

Significance:

Hyperspectral imaging (HSI) can support intraoperative perfusion assessment, the identification of tissue structures, and the detection of cancerous lesions. The practical use of HSI for minimal-invasive surgery is currently limited, for example, due to long acquisition times, missing video, or large set-ups.

Aim:

An HSI laparoscope is described and evaluated to address the requirements for clinical use and high-resolution spectral imaging.

Approach:

Reflectance measurements with reference objects and resected human tissue from 500 to 1000 nm are performed to show the consistency with an approved medical HSI device for open surgery. Varying object distances are investigated, and the signal-to-noise ratio (SNR) is determined for different light sources.

Results:

The handheld design enables real-time processing and visualization of HSI data during acquisition within 4.6 s. A color video is provided simultaneously and can be augmented with spectral information from push-broom imaging. The reflectance data from the HSI system for open surgery at 50 cm and the HSI laparoscope are consistent for object distances up to 10 cm. A standard rigid laparoscope in combination with a customized LED light source resulted in a mean SNR of 30 to 43 dB (500 to 950 nm).

Conclusions:

Compact and rapid HSI with a high spatial- and spectral-resolution is feasible in clinical practice. Our work may support future studies on minimally invasive HSI to reduce intra- and postoperative complications.

Intraoperative Assessment of Gastric Sleeve Oxygenation Using Hyperspectral Imaging in Esophageal Resection: A Feasibility Study

(DOI: 10.1159/000509304)

Schwandner F, Hinz S, Witte M, Philipp M, Schafmayer C, Grambow E

2020

Visceral Medicine

Introduction:

Sufficient tissue oxygenation is essential for anastomotic healing in visceral surgery. Hyperspectral imaging (HSI) is a noncontact, noninvasive technique for clinical assessment of tissue oxygenation in real time.

Methods:

In this case series, HSI was used in 4 patients who were admitted for either esophageal cancer or cardiac carcinoma (AEG type I or II). Thoraco-abdominal surgical esophageal resection was performed after staging and neoadjuvant therapy. Intraoperative oxygenation of superficial (StO_2) and underlying tissue (NIR perfusion index) of the gastric sleeve were studied intrathoracic by means of the TIVITA® Tissue HSI camera. This was performed prior to esophagogastric anastomosis. The postoperative course, especially in view of surgical complications, was recorded.

Results:

Assessment of StO_2 and NIR perfusion index was performed in 4 regions of interest per gastric sleeve, aboral and oral of the clinically determined resection line. It allowed the fast quantification of gastric oxygenation prior gastroesophageal anastomosis. Median StO_2 aboral of the determined resection line was 69%, while median StO_2 in the oral part of the gastric sleeve was found at 53%. In contrast, the median NIR perfusion index was similar aboral (80) and oral (82) of the resection line. In none of the 4 studied patients, an anastomotic failure appeared.

Discussion/Conclusion:

This report suggests that HSI is a feasible technique for intraoperative assessment of tissue oxygenation before gastroesophageal anastomosis and might reduce the incidence of anastomotic failure in the gastrointestinal tract

Hyperspectral imaging system for monitoring laser-induced thermal damage in gastric mucosa

(DOI: 10.1109/MeMeA49120.2020.9137230)

De Landro M, Barberio M, Felli E, Agnus V, Pizzicannella M, Diana M, Saccomandi P

2020

International Symposium on Medical Measurements and Applications

Minimally invasive techniques are gaining a major role in treating superficial gastrointestinal cancers.

Energy-based approaches have been investigated as potential alternative to the gold-standard techniques (e.g., Endoscopic Submucosal Dissection). Among these techniques, the laser has been studied for achieving a selective ablation of the gastric mucosa. Together with the optimization of the laser settings for avoiding tissue perforation or insufficient ablation, a tool providing quantitative information about the intraoperative tissue state can support the treatment guidance.

This work aims at providing a novel non-invasive approach based on the use of hyperspectral imaging (HSI) for monitoring ablative therapy in in vivo gastric mucosa. The three-dimensional datasets generated by the HSI provide spatial and spectral information of the scene, thus collecting tissue optical features during the ablation therapy in each pixel of the images.

The operation of a diode laser focused on the porcine gastric mucosa was controlled in accordance with chosen temperature thresholds (i.e., 36, 60, 70, 80, 100, 110 °C), measured with a thermographic camera. HSIs of the living gastric mucosa undergoing laser procedure hold diagnostic information about the thermal outcome. Two tests have been performed, and the temperature dependence of three characteristic spectral wavelengths have been analysed: oxyhemoglobin (Hb02) in the visible range 500-600 nm, methemoglobin (metHb) around 630 nm, and deoxyhemoglobin (Hb) at 760 nm. The data have been processed in terms of absorbance at the set temperature relative to the absorbance at initial body temperature (36 °C). After 60 °C the percentage relative absorbance of metHb increased significantly in both tests (i.e., 92.3±1.9 % at 70 °C and 229.4±4.7% at 100 °C in Test2); regarding the Hb at 110 °C, Test1 reported an increase of 43.8±1.7 %, versus 127.2±3.8% in the Test2. On the other hand, HbO2 chromophore experiences an increase only for the first stages of heating later decreasing in favour of metHb and Hb formation.

In both tests, similar trends for characteristic wavelengths are found, thus demonstrating the potential of the HSI measurement in laser-induced thermal damage monitoring. Although optical response show dependence on the tissue type and condition, this finding encourages future studies to standardize this promising technique.

Hyperspectral Imaging (HSI) in Acute Mesenteric Ischemia to Detect Intestinal Perfusion Deficits

(DOI: 10.1016/j.jss.2020.04.001)

Mehdorn M, Köhler H,Rabe S M, Niebisch S, Lyros O, Chalopin C, Gockel I, Jansen-Winkeln B

2020

Journal of Surgical Research

Background

Acute mesenteric ischemia is a life-threatening acute condition, which requires an interdisciplinary approach, including vascular recanalization and surgical treatment. Visual evaluation of intestinal perfusion might be misleading, and therefore, additional tools are necessary to reliably be able to resect the ischemic intestine. Hyperspectral imaging (HSI) has been shown to be feasible and safe for real-time assessment of tissue perfusion in visceral surgery but has never been used in cases of acute mesenteric ischemia. Therefore, we applied HSI in acute mesenteric ischemia to evaluate it for potential aid in the objectively discriminating ischemic and well-perfused intestine during explorative laparotomy.

Methods

We recorded HSI measurements in 11 cases of acute mesenteric ischemia during explorative laparotomy. We evaluated the recorded images for macroscopic visual perfusion quality and divided it into three groups. Of those three groups, we calculated and compared the HSI indexes of tissue saturation, near-infrared perfusion index, organ hemoglobin index, and tissue water index, as well as the reflectance spectra.

Results

We found significant differences in tissue saturation (0.7% versus 0.45%; $P = 0.002$) and near-infrared perfusion index (0.58 versus 0.23; $P < 0.001$) in poorly perfused intestinal segments compared with the viable intestine. Furthermore, we could detect an increasing peak at 630 nm of the reflectance spectra in less viable tissues, indicating a maximum in necrotic tissues. We attributed this peak to an increase in met-hemoglobin content in necrotic tissues, which is supported by the increase in the HSI organ hemoglobin index.

Conclusions

HSI is able to discriminate tissue perfusion in acute mesenteric ischemia reliably and therefore might be helpful for resection. In addition, HSI gives information on tissue viability via reflectance spectra.

Hyperspectral enhanced reality (HYPER) for anatomical; liver resection

(DOI: 10.1007/s00464-020-07586-5)

Urade T, Felli E, Barberio M, Al-Taher M, Felli E, Goffin L, Agnus V, Ettorre G M, Marescaux J, Mutter D, Diana M

2020

Surgical Endoscopy

Background

Clinical evaluation of the demarcation line separating ischemic from non-ischemic liver parenchyma may be challenging. Hyperspectral imaging (HSI) is a noninvasive imaging modality, which combines a camera with a spectroscope and allows quantitative imaging of tissue oxygenation. Our group developed a software to overlay HSI images onto the operative field, obtaining HSI-based enhanced reality (HYPER). The aim of the present study was to evaluate the accuracy of HYPER to identify the demarcation line after a left vascular inflow occlusion during an anatomical left hepatectomy.

Materials and methods

In the porcine model (n = 3), the left branches of the hepatic pedicle were ligated. Before and after vascular occlusion, HSI images based on tissue oxygenation (StO2), obtained through the Near-Infrared index (NIR index), were regularly acquired and superimposed onto RGB video. The demarcation line was marked on the liver surface with electrocautery according to HYPER. Local lactates were measured on blood samples from the liver surface in both ischemic and perfused segments using a strip-based device. At the same areas, confocal endomicroscopy was performed.

Results

After ligation, HSI demonstrated a significantly lower oxygenation (NIR index) in the left medial lobe (LML) (0.27%±0.21) when compared to the right medial lobe (RML) (58.60%±12.08; p=0.0015). Capillary lactates were significantly higher (3.07 mmol/L±0.84 vs. 1.33 ±0.71 mmol/L; p= 0.0356) in the LML versus RML, respectively. Concordantly, confocal videos demonstrated the absence of blood flow in the LML and normal perfusion in the RML.

Conclusions

HYPER has made it possible to correctly identify the demarcation line and quantify surface liver oxygenation. HYPER could be an intraoperative tool to guide perfusion-based demarcation line assessment and segmentation.

Hybridösophagektomie mit intraoperativem Hyperspektral-Imaging

(DOI: 10.1007/s00104-020-01139-1)

Moulla Y, Reifenrath M, Rehmet K, Niebisch S, Jansen-Winkeln B, Sucher R, Hoffmeister A, Kreuser N, Köhler H, Gockel I

2020

Der Chirurg

Die Technik der Hybridösophagektomie mit systematischer 2-Feld-Lymphadenektomie beim Ösophaguskarzinom zeigte in einer aktuell publizierten prospektiv-randomisierten Studie eine signifikante Reduktion der postoperativen Morbidität. In unserem Videobeitrag stellen wir das abdominothorakale Hybridvorgehen mit (1.) laparoskopischer Gastrolyse und ischämischer Konditionierung des Magens und (2.) zweizeitiger transthorakaler Ösophagektomie mit Magenhochzug, intrathorakaler Schlauchmagenbildung und Anastomosierung dar. Das intraoperative Hyperspektral-Imaging (HSI) während des thorakalen Teils der Operation dient der Identifikation der ideal perfundierten Anastomosenregion.

Classification of Barrett's carcinoma specimens by hyperspectral imaging (HSI)

(DOI: 10.1093/dote/doz092.129)

Thieme R, Maktabi M., Köhler H., Chalopin C., Jansen-Winkeln B., Gockel I

2019

Diseases of the Esophagus

Aim

Hyperspectral imaging (HSI) technology combines imaging with spectroscopy and can be used for the classification of malignant and non-malignant cells. Thereby HSI combined with artificial intelligent algorithms can be used to predict tumor cells in in Barrett's carcinoma specimens.

Methods

HSI imaging records light between the visual and near-infrared light (500-1000nm). For a first feasibility study, this technique was used to discriminate between squamous epithelium and esophageal adenocarcinoma, and 45 specimens from Barrett's carcinoma patients were recorded. 22 of the 45 investigated specimens contained also squamous epithelium. The specimens were fixed routinely after resection in paraformaldehyde, were sliced to 3µm, and were stained by haematoxylin and eosin (HE). A non-parametric supervised classification learning algorithm (K-nearest neighbours (k-NN)) was used for discrimination.

Results

Barrett's adenocarcinoma cells were recorded by HSI in all 45 investigated cases. Squamous epithelium and Barrett's adenocarcinoma cells displayed differences in the absorbance between the wave lengths of 500 to 700 nm. For both, the squamous epithelium and the Barrett's adenocarcinoma cells, the intra group variances of the investigated specimens were quite low. 333,275 and 74,000 spectra could be measured from Barrett's adenocarcinoma and from squamous epithelium, respectively. Specificity, sensitivity and precision with a k-NN (k=5) classifier were 0.74, 0.92 and 0.94 for the presence of Barrett's adenocarcinoma cells.

Conclusions

HE-stained squamous epithelium and Barrett's adenocarcinoma cells showed specific spectral alterations, when measured by HSI. These characteristics could be used in the future to develop a computer-assisted algorithm to discriminate semi-automated for tumor cells Barrett's carcinoma specimens, which will help to foster decision-making support in histopathological diagnosis.

Intraoperative imaging / Visceral chirurgy

Automatic tumor tissue classification of oncological esophageal resectates based on hyperspectral data

(DOI: 10.1055/s-0039-1695116)

Maktabi M, Köhler H, Thieme R, Takoh J P, Rabe S M, Jansen-Winkeln B, Gockel I, Chalopin C

2019

Zeitschrift für Gastroenterologie

Hyperspectral imaging (HSI) is a non-invasive and contactless optical technique which combines imaging with spectroscopy. Tissue is illuminated and the light reflected by the object is acquired by a camera and analyzed by a spectrometer. The generated 3D data are called hypercubes. A reflectance spectrum corresponds to each point of the examined object surface. HSI showed to be very useful in the monitoring of wounds, the assessment of tissue perfusion and the identification of anatomical structures. However, the generated raw data are complex to understand and have to be processed before being presented to physicians. In this work, automatic machine-learning classification approaches were evaluated for the identification of tumor in ex vivo tissue.

The HSI system TIVITA (Diaspective Vision GmbH) was used during hybrid or open surgeries. Tissue and structures depicted in the hypercubes were annotated based on the final histological report. 370,425 spectra of esophagus, 147,446 spectra of stomach tissue and 130,744 spectra of cancer tissue of 10 patients were used to train the classification algorithms. Trainings and tests were performed with a stochastic gradient descent approach.

Sensitivity values of 92%, 56% and 24% as well as precision values of 45%, 84% and 86% were obtained for stomach, esophagus and carcinoma. The main limitations of the automatic classification are the use of ex vivo tissue and possible errors in the ground truth.

These first results demonstrated that machine learning methods are suitable to automatically discriminate tissue using HSI. Moreover, the computing time is acceptable for intraoperative use. Further developments of the algorithms and the use of larger patient datasets are necessary to improve the classification results.

Hyperspektrales Imaging zur Diskrimination des Resektionsausmaßes im Rahmen der akuten Mesenterialischämie

(DOI: 10.1055/s-0039-1695182)

Mehdorn M, Rabe S M, Köhler H, Maktabi M, Takoh J P, Neumuth T, Melzer A, Moulla Y, Chalopin C, Jansen-Winkeln B, Gockel I

2019

Zeitschrift für Gastroenterologie

Einleitung:

Die Akute Mesenterialischämie ist ein akut lebensbedrohliches Krankheitsbild, welches ein interdisziplinäres Therapiekonzept benötigt, da die Ursache häufig ein Verschluss der Arteria mesenterica superior (AMS) ist. Im Rahmen dessen entsteht eine Nekrose des abhängigen Darmes. Ziel der Therapie ist die Revaskularisation gefolgt von der operativen Entfernung nekrotischen Darmes. Die Radikalität der Resektion ist entscheidend für das weitere Voranschreiten der Erkrankung und die spätere Lebensqualität des Patienten, ist jedoch aktuell nur anhand subjektive Parameter möglich.

Ziele:

Es soll hier eine Evaluation der diagnostischen Wertigkeit der Hyperspektralen Bildgebung im Rahmen der akuten Mesenterialischämie als potenzielles Hilfsmittel zur Bestimmung des Resektionsausmaßes an Hand einer Fallserie erfolgen.

Methodik:

Bei insgesamt 7 Patienten wurde eine Hyperspektrale Bildgebung im Rahmen der Explorativlaparotomie im Rahmen einer akuten Mesenterialischämie aufgezeichnet. Es erfolgte eine Auswertung des klinischen Verlaufs der Patienten, der RGB-Fotos mit Hinweis auf die subjektiv eingeschätzte Vitalität und die in der Software gemessenen unterschiedlichen Indices wie Perfusionsindex, der Gewebesättigung oder nekrosespezifischer Emissionspeaks.

Ergebnis:

Es wurden insgesamt 7 Patienten untersucht, davon überlebten 2 Patienten und konnten entlassen werden. 6 von 7 hatten einen Verschluss im AMS-Stromgebiet, einer einen AMI-Verschluss. Im Vergleich zu gesunden Darmabschnitten, deren HSI-Messungen im Rahmen elektiver Operationen aufgezeichnet wurden, waren die o. g. Indizes in Darmregionen mit makroskopisch grenzwertiger Perfusion bereits deutlich unterschiedlich.

Schlussfolgerung:

Anhand unserer Fallserie ergeben sich Hinweise, dass die Hyperspektrale Bildgebung in Zukunft als Hilfsmittel in der Entscheidungsfindung bezüglich des Resektionsausmaßes im Rahmen der akuten Mesenterialischämie verwendet werden kann. Für einen zuverlässigen Einsatz ist ein verbreiteterer Einsatz auch im Rahmen anderer Operationen notwendig, um letzten Endes Grenzwerte definieren zu können.

Möglichkeiten und Perspektiven der Hyperspektralbildgebung in der Viszeralchirurgie

(DOI: 10.1007/s00104-019-01016-6)

Gockel I, Jansen-Winkeln B, Holfert N, Rayes N, Thieme R, Maktabi M, Sucher R, Seehofer D, Barberio M, Diana M, Rabe S, Mehdorn M, Moulla Y, Niebisch S, Branzan D, Rehmet K, Takoh J P, Petersen TO, Neumuth T, Köhler H

2019

Der Chirurg

Die Hyperspektralbildgebung („HyperSpectral Imaging“ [HSI]) erlaubt quantitative Gewebeanalysen über die Limitationen des menschlichen Auges hinaus. Somit dient sie als neues Diagnostikinstrument der optischen Eigenschaften verschiedener Gewebe. Im Gegensatz zu anderen intraoperativen bildgebenden Methoden ist HSI kontaktlos, nichtinvasiv und bedarf keiner Kontrastmittelapplikation. Die Messungen nehmen nur wenige Sekunden in Anspruch und stören somit die Operationsabläufe unwesentlich. Erste HSI-Anwendungen in der Viszeralchirurgie sind vielversprechend mit dem Potenzial optimierter Ergebnisse.

Aktuelle Konzepte, Möglichkeiten und neue Perspektiven der HSI-Technologie sowie deren Limitationen werden in dieser Arbeit diskutiert.

Bestimmung der idealen Anastomosenposition durch hyperspectrale Bildgebung

(DOI: 10.1055/s-0039-1695193)

Jansen-Winkeln B, Holfert N, Köhler H., Chalopin C, Gockel I

2019

Zeitschrift für Gastroenterologie

Einleitung:

Anastomoseninsuffizienzen sind gefürchtete Komplikationen in der Viszeralchirurgie. Bei links-kolorektalen Resektionen wird die Perfusion vordringlich durch die Absetzungsebene am Colon descendens definiert. Hier ist die Durchblutung nach Absetzen der zentralen Gefäße durch die Randarkade gewährleistet. Eine gute Durchblutung der zu anastomosierenden Enden ist Voraussetzung für eine gute Anastomosenheilung.

Ziele:

Es soll gezeigt werden, dass mit der Hyperspektralbildgebung (HSI) eine objektivierbare und sichere Methode vorliegt um die ideale Anastomosenposition zu bestimmen.

Material und Methoden:

Eingeschlossen sind in dieser prospektiven, einarmigen, nicht randomisierten klinischen Studie 37 Patienten mit links-kolorektalen Resektionen in dem Zeitraum von Februar 2018 bis April 2019. Es konnten bei 31 Patienten auswertbare Messungen der Perfusion mit der Hyperspektralkamera durchgeführt werden. Die Hyperspektralkamera kann Licht im nicht-sichtbaren Bereich aufzeichnen und so durch spezifische und validierte Reflexionsmuster im Nah-Infraroten Bereich z. B. die Perfusion und Sauerstoffsättigung in oberflächlichen Schichten, in tieferen Schichten oder die Hämoglobinkonzentration darstellen. Vor Messung wird die geplante Resektionsgrenze festgelegt. Die Messungen mit der Kamera erfolgen über 4 Minuten nach Durchtrennen der Randarkade. Zur Auswertung werden in 5 mm Abständen Messzonen mit einem Durchmesser von 5 mm bestimmt und so über 10 cm die Parameter bestimmt.

Ergebnisse:

Die Hyperspektralkamera kann die Durchblutung präzise auswerten und zeigt einen Abfall der Sauersoffsättigung (StO_2) innerhalb von 2 Minuten nach der Durchtrennung der Randarkade auf ein Gleichgewicht. Gleichzeitig steigt die StO_2 proximal etwas an. Die Grenzzone demarkiert sich innerhalb von einem cm. Die vor der Messung definierte Resektionsgrenze wurde auf Grund der HSI-Bilder in 11 Fällen nach proximal verschoben.

Schlussfolgerung:

Die ideale Anastomosenposition kann mit der Hyperspektralkamera objektivierbar und kontaktlos ohne Kontrastmittel eindeutig definiert werden.

Tissue classification of oncologic esophageal resectates based on hyperspectral data

(DOI: 10.1007/s11548-019-02016-x)

Maktabi M, Köhler H, Ivanova M, Takoh J P, Rabe S M, Jansen-Winkeln B, Niebisch S, Gockel I, Chalopin C

2019

International Journal of CARS

Purpose

Esophageal carcinoma is the eighth most common cancer worldwide. Esophageal resection with gastric pull-up is a potentially curative therapeutic option. After this procedure, the specimen is examined by the pathologist to confirm complete removal of the cancer. An intraoperative analysis of the resectate would be less time-consuming and therefore improve patient safety.

Methods

Hyperspectral imaging (HSI) is a relatively new modality, which has shown promising results for the detection of tumors. Automatic approaches could support the surgeon in the visualization of tumor margins. Therefore, we evaluated four supervised classification algorithms: random forest, support vector machines (SVM), multilayer perceptron, and k-nearest neighbors to differentiate malignant from healthy tissue based on HSI recordings of esophago-gastric resectates in 11 patients.

Results

The best performances were obtained with a cancerous tissue detection of 63% sensitivity and 69% specificity with the SVM. In a leave-one patient-out cross-validation, the classification showed larger performance differences according to the patient data used. In less than 1 s, data classification and visualization was shown.

Conclusion

In this work, we successfully tested several classification algorithms for the automatic detection of esophageal carcinoma in resected tissue. A larger data set and a combination of several methods would probably increase the performance. Moreover, the implementation of software tools for intraoperative tumor boundary visualization will further support the surgeon during oncologic operations.

Hyperspectral imaging as a new optical method for the measurement of gastric conduit perfusion

(DOI: 10.1093/dote/doz046)

Köhler H, Jansen-Winkeln B, Chalopin C, Gockel I

2019

Diseases of the Esophagus

Letter to the Editor:

Dear Editors,

With great interest, we read the review article by Jansen et al.1 published in Diseases of the Esophagus in June 2018. The authors provide a comprehensive overview of optical techniques used for the measurement of gastric conduit perfusion. They emphasize the importance of sufficient gastric perfusion to prevent postoperative anastomotic leakage after esophagectomy. The review article includes six different optical imaging methods for quantitative estimation of perfusion change and prediction of necrosis or anastomotic leakage. Despite individual limitations, optical techniques are described as valuable for the evaluation of perfusion in gastric tube surgery. A clear need for an intraoperative method with objective quantitative parameters ready to use in human studies is reported. The missing gold standard for the quantitative validation of perfusion parameters remains an unsolved problem. The authors conclude that a threshold value for the prediction of anastomotic leakage needs to be determined.

We would like to supplement another optical imaging method called hyperspectral imaging (HSI). In recent years, HSI has gained popularity for different medical applications. Our own group showed for the first time the in vivo application of HSI during gastrointestinal surgery in humans. Recently, we showed that HSI is suitable for noninvasive and intraoperative evaluation of ischemic conditioning effects of the gastric conduit. We strongly agree with Jansen et al. that additional studies are needed to determine normal values and thresholds for physiologic tissue parameters. Even though a gold standard for the validation of perfusion parameters is missing, HSI provides objective and quantitative values for tissue oxygenation, similar to near-infrared spectroscopy, but with high spatial resolution.

Evaluation of hyperspectral imaging (HSI) for the measurement of ischemic conditioning effects of the gastric conduit during esophagectomy

(DOI: 10.1007/s00464-019-06675-4)

Köhler H, Jansen-Winkeln B, Maktabi M, Barberio M, Takoh J P, Holfert N, Moulla Y, Niebisch S, Diana M, Neumuth T, Rabe S M, Chalopin C., Melzer A, Gockel I

2019

Surgical endoscopy

Background

Hyperspectral imaging (HSI) is a relatively new method used in image-guided and precision surgery, which has shown promising results for characterization of tissues and assessment of physiologic tissue parameters. Previous methods used for analysis of preconditioning concepts in patients and animal models have shown several limitations of application. The aim of this study was to evaluate HSI for the measurement of ischemic conditioning effects during esophagectomy.

Methods

Intraoperative hyperspectral images of the gastric tube through the mini-thoracotomy were recorded from n = 22 patients, 14 of whom underwent laparoscopic gastrolysis and ischemic conditioning of the stomach with two-step transthoracic esophagectomy and gastric pull-up with intrathoracic anastomosis after 3–7 days. The tip of the gastric tube (later esophagogastric anastomosis) was measured with HSI. Analysis software provides a RGB image and 4 false color images representing physiologic parameters of the recorded tissue area intraoperatively. These parameters contain tissue oxygenation (StO_2), perfusion—(NIR Perfusion Index), organ hemoglobin (OHI), and tissue water index (TWI).

Results

Intraoperative HSI of the gastric conduit was possible in all patients and did not prolong the regular operative procedure due to its quick applicability. In particular, the tissue oxygenation of the gastric conduit was significantly higher in patients who underwent ischemic conditioning ($\overline{StO_2}_{Precond.}$ = 78%; $\overline{StO_2}_{NoPrecond.}$ = 66%; $p = 0.03$).

Conclusions

HSI is suitable for contact-free, non-invasive, and intraoperative evaluation of physiological tissue parameters within gastric conduits. Therefore, HSI is a valuable method for evaluating ischemic conditioning effects and may contribute to reduce anastomotic complications. Additional studies are needed to establish normal values and thresholds of the presented parameters for the gastric conduit anastomotic site.

Determination of the transection margin during colorectal resection with Hyperspectral Imaging (HSI)

(DOI: 10.1007/s00384-019-03250-0)

Jansen-Winkeln B, Holfert N, Köhler H, Moulla Y, Takoh J P, Rabe S M, Mehdorn M, Barberio M, Chalopin C, Neumuth T, Gockel I

2019

International Journal of Colorectal Disease

Purpose

This study evaluated the use of hyperspectral imaging for the determination of the resection margin during colorectal resections instead of clinical macroscopic assessment.

Methods

The used hyperspectral camera is able to record light spectra from 500 to 1000 nm and provides information about physiologic parameters of the recorded tissue area intraoperatively (e.g., tissue oxygenation and perfusion). We performed an open-label, single-arm, and non-randomized intervention clinical trial to compare clinical assessment and hyperspectral measurement to define the resection margin in 24 patients before and after separation of the marginal artery over 15 min; HSI was performed each minute to assess the parameters mentioned above.

Results

The false color images calculated from the hyperspectral data visualized the margin of perfusion in 20 out of 24 patients precisely. In the other four patients, the perfusion difference could be displayed with additional evaluation software. In all cases, there was a deviation between the transection line planned by the surgeon and the border line visualized by HSI (median 1 mm; range − 13 to 13 mm).

Tissue perfusion dropped up to 12% within the first 10 mm distal to the border line. Therefore, the resection area was corrected proximally in five cases due to HSI record. The biggest drop in perfusion took place in less than 2 min after devascularization.

Conclusion

Determination of the resection margin by HSI provides the surgeon with an objective decision aid for assessment of the best possible perfusion and ideal anastomotic area in colorectal surgery.

Neue Sicht der Dinge

(DOI: ./.)

Gockel I, Takoh J P, Rabe S M, Chalopin C, Köhler H, Jansen-Winkeln B

2018

KTM Krankenhaus Technik + Management

Die Klinik für Viszeral-, Transplantations-, Thorax- und Gefäßchirurgie am Universitätsklinikum Leipzig und das Innovation Center Computer Assisted Surgery der Universität Leipzig forschen gemeinsam an der so genannten intraoperativen Hyperspektral-Bildgebung. Ziel ist es, diese Methode zur Beurteilung gastrointestinaler Anastomosen in der viszeralchirurgischen Routine zu etablieren – nicht zuletzt auch aufgrund der nicht-invasiven, kontaktfreien Messungen, der intraoperativen Anwenderfreundlichkeit bei nur minimal längerer OP-Dauer sowie der geringen Wartungs- und Betriebskosten.

Die intraoperative Hyperspektral-Bildgebung in der Viszeralchirurgie

(DOI: ./.)

Gockel I, Takoh J P, Chalopin C, Jansen-Winkeln B

2018

Ärzteblatt Sachsen

Die Hyperspektral-Bildgebung (HSI = HyperSpectral Imaging) ist ein neues Bildgebungsverfahren, das für die Erkennung von Strukturen und für die Auswertung der Gewebedurchblutung, -oxygenierung sowie dessen Wasserhaushalts in der Wundtherapie vielversprechende Ergebnisse gezeigt hat. Wir konnten das System erstmals nutzen, um in vivo gastrointestinale Anastomosen in der Viszeralchirurgie zu beurteilen.

HSI bietet als kontaktfreie, nicht-invasive und kontrastmittellose intra-operative Bildgebungsmethode eine objektive „real time"-Messung physiologischer Anastomosenparameter, die möglicherweise dazu beitragen kann, die „ideale" Anastomosenregion /-höhe zu determinieren, um somit im Sinne der Präzisionsmedizin potenziell zu mehr Sicherheit für die Anastomosenheilung beizutragen.

Hyperspectral Imaging bei gastrointestinalen Anastomosen

(DOI: 10.1007/s00104-018-0633-2)

Jansen-Winkeln B, Maktabi M, Takoh J P, Rabe S M, Barberio M, Köhler H, Neumuth T, Melzer A, Chalopin C, Gockel I

2018

Der Chirurg

Einleitung

Anastomoseninsuffizienzen (AIs) sind die schwerwiegendsten Komplikationen in der gastrointestinalen Chirurgie mit assoziierter Verlängerung des stationären Aufenthalts und signifikanter Mortalität. Hyperspektralbildgebung („hyperspectral imaging“, HSI) ist ein relativ neues Bildgebungsverfahren, das für die Erkennung von Strukturen und für die Auswertung der Gewebedurchblutung, -oxygenierung sowie des Wasserhaushalts in der Wundtherapie vielversprechende Ergebnisse gezeigt hat. Zur In-vivo-Beurteilung gastrointestinaler Anastomosen liegen allerdings bisher noch keine Daten vor.

Methodik

Es wurde die intraoperative HS-Bildgebung mit dem TIVITA™ Tissue-Kamerasystem der Firma Diaspective Vision GmbH (Pepelow, Deutschland) angewandt. Bei 47 Patienten mit gastrointestinalen (GI) Anastomosen an Ösophagus, Magen, Pankreas, Dünn- und Dickdarm sowie Rektum wurden 97 auswertbare Aufnahmen generiert. Es wurden an den Anastomosen die Parameter Gewebeoxygenierung („tissue O_2 saturation“, StO_2), Gewebe-Hämoglobin-Index („tissue hemoglobin index“, THI), Nahinfrarot-Perfusions-Index („near-infrared [NIR] perfusion index“) und Gewebe-Wasser-Index („tissue water index“, TWI) erhoben.

Ergebnisse

Die Anwendung der nichtinvasiven HSI war bei allen Anastomosierungen technisch gut praktikabel mit robusten Ergebnissen. Dabei fand sich ein NIR-Gradient längs und quer entlang der Anastomose. Auch die Gewebewasserverteilung und -oxygenierung zeigten spezifische Verläufe rund um die Anastomosenregion.

Schlussfolgerung

HSI bietet als kontaktfreie, nichtinvasive und kontrastmittellose intraoperative Bildgebungsmethode eine objektive Real-time-Messung physiologischer Anastomosenparameter, die möglicherweise dazu beitragen kann, die „ideale“ Anastomosenregion/-höhe zu determinieren. Hierzu ist eine weitere Etablierung der Methodik in der Viszeralchirurgie mit Generierung von Norm- bzw. Cut-off-Werten für die unterschiedlichen intestinalen Anastomosenarten erforderlich.

Image-guided surgery: Einsatz von Hyperspektralbildgebung in der Viszeralchirurgie

(DOI: ./.)

Gockel I, Chalopin C, Kulcke A, Takoh J P, Barberio M, Jansen-Winkeln B, Rabe S M, Maktabi M, Köhler H, Neumuth T, Diana M, Melzer A

2017

CTAC-Newsletter

Hyperspektralbildgebung (HSI für „hyperspectral imaging“) ist ein relativ neues Bildgebungsverfahren in der Medizin. Das kontaktlose Verfahren kombiniert das Prinzip der Spektroskopie mit der Bildgebung, die man von herkömmlichen visuellen Kameras kennt. Dabei wird das untersuchte Gewebe mit Licht im visuellen Spektrum beleuchtet und das vom Gewebe remittierte Licht gemessen. Es wird ein dreidimensionaler Würfel, der sogenannte Hypercube, erzeugt, der aus räumlichen und spektralen Informationen besteht und jeder Pixel eine spektrale Signatur enthält. Aus den gemessenen Lichtspektren werden Indexe wie Hämoglobinverteilung, Sauerstoffsättigung, Nahinfrarotperfusion oder Wasserindex berechnet, deren Werte in Bildintensitäten zur Visualisierung codiert werden können. Diese Modalität erfordert keine Gabe eines Kontrastmittels. Zudem kann HSI im Vergleich zu anderen optischen Bildgebungsverfahren die unteren Schichten von Gewebe von maximal einem Zentimeter untersuchen.

Classification of Hyperspectral Endocrine Tissue Images Using Support Vector Machines

(DOI: 10.1002/rcs.2121)

Maktabi M,Köhler H,Ivanova M, Neumuth T, Rayes N, Seidemann L, Sucher R, Jansen-Winkeln B, Gockel I, Barberio M, Chalopin C

2020

International Journal of Medical Robotics and Computer Assisted Surgery

Thyroidectomy is one of the most commonly performed surgical procedures. The region of the neck has a very complex structural organization. It would be beneficial to introduce a tool that can assist the surgeon in tissue discrimination during the procedure.

One such solution is the non-invasive and contactless technique, called hyperspectral imaging (HSI). To interpret the HSI data, we implemented a supervised classification method to automatically discriminate the parathyroid, the thyroid and the recurrent laryngeal nerve (RLN) from surrounding tissue (muscle, skin) and materials (instruments, gauze).

A one-leave-out-patient cross-validation was performed. The best performance was obtained using support vector machine (SVM) with a classification and visualization in less than 1.4 seconds. A mean patient accuracy of 68 ± 23% was obtained for all tissues and material types.

The proposed method showed promising results and have to be confirmed on a larger cohort of patient data.

Hyperspectral based discrimination of thyroid and parathyroid during surgery

(DOI: 10.1515/cdbme-2018-0095)

Barberio M, Maktabi M, Gockel I, Rayes N, Jansen-Winkeln B, Köhler H, Rabe S M, Seidemann L, Takoh J P, Diana M, Neumuth T, Chalopin C

2018

Current Directions in Biomedical Engineering

Unintended injuring of anatomical structures during endocrine neck operations can have severe consequences for patient. Especially the nerves and the parathyroid gland can be hard to identify visually. Therefore, intraoperative methods are needed to support the surgeon in this task.

Hyperspectral imaging (HSI) is a new approach in the medical area which combines a camera with a spectrometer. It showed promising results for the discrimination of tissue. In this work, HSI-data of seven patients were acquired during thyroid and parathyroid operations. The mean absorbance spectra of both glands showed differences in the range between 600 and 700 nm and at 760 and 960 nm. This means that thyroid and parathyroid have different oxygenation states and different contents of deoxygenated hemoglobin and water. From these observations, it is possible to define spectral signatures to characterize both glands. We showed on one patient, how spectral signatures can be used in classification algorithms to automatically identify the thyroid and parathyroid from other structures.

Was ist neu in ... der hyperspektralen Bildgebung
Eine Technologie der Zukunft für das hämodynamische Monitoring

(DOI: 10.1007/s00101-020-00892-6)

Dietrich M, Marx S, Bruckner T, Nickel F, Müller-Stich B P, Hackert T, Weigand M A, Uhle F, Brenner T, Schmidt K

2020

Der Anaesthesist

Der Einsatz von bildgebenden Verfahren zur direkten Evaluation der Gewebeperfusion und - oxygenierung ist bislang kein etablierter Bestandteil des perioperativen und intensivmedizinischen Monitorings. Eine innovative hyperspektrale Bildgebungstechnologie könnte nun sowohl eine kontextsensitive Mikrozirkulationsdiagnostik als auch gewebeperfusionsorientierte hämodynamische Therapieansätze ermöglichen

Perfusion imaging

Bedside hyperspectral imaging for the evaluation of microcirculatory alterations in perioperative intensive care medicine: a study protocol for an observational clinical pilot study (HySpI-ICU)

(DOI: 10.1136/bmjopen-2019-035742)

Dietrich M, Marx S, Bruckner T, Nickel F, Müller-Stich B P, Hackert T, Weigand M A, Uhle F, Brenner T, Schmidt K

2020

BMJ Open

Introduction

Normalisation of macrocirculatory parameters during resuscitation therapy does not guarantee the restoration of microcirculatory perfusion in critical illness due to haemodynamic incoherence. Persistent microcirculatory abnormalities are associated with severity of organ dysfunction and mandate the development of bedside microcirculatory monitoring. A novel hyperspectral imaging (HSI) system can visualise changes in skin perfusion, oxygenation and water content at the bedside. We aim to evaluate the effectiveness of HSI for bedside monitoring of skin microcirculation and the association of HSI parameters with organ dysfunction in patients with sepsis and major abdominal surgery.

Methods and analysis

Three independent groups will be assessed and separately analysed within a clinical prospective observational study: (1) 25 patients with sepsis or septic shock (according to sepsis-3 criteria), (2) 25 patients undergoing pancreatic surgery and (3) 25 healthy controls. Patients with sepsis and patients undergoing pancreatic surgery will receive standard therapy according to local protocols derived from international guidelines. In addition, cardiac output of perioperative patients and patients with sepsis will be measured. Healthy controls undergo one standardised evaluation. The TIVITA Tissue System is a novel HSI system that uses the visible and near-infrared spectral light region to determine tissue microcirculatory parameters. HSI analysis (hand/knee) will be done in parallel to haemodynamic monitoring within defined intervals during a 72-hour observation period. HSI data will be correlated with the Sequential Organ Failure Assessment score, global haemodynamics, inflammation and glycocalyx markers, surgical complications and 30-day outcome.

Perfusion imaging

Hyperspectral Imaging Quantification of Mouse Limb Microcirculation Using an Ischemia Reperfusion Model with Phosphodiesterase 5 Inhibitor Preconditioning

(DOI: 10.1089/lap.2020.0364)

Barberio M, Felli E, Diana M, Marescaux J, Al-Taher M, Georg I, Tetsi L, Lejay A, Charles A L, Lugnier C, Geny B

2020

Journal of Laparoendoscopic & Advanced Surgical Techniques

Background:

Peripheral arterial disease has high incidence and complication rates. Vessel recanalization represents the main therapy. However, it induces reperfusion injury. Preconditioning with sildenafil has been advocated to protect against this injury. In this study, we show a real-time noninvasive quantitative assessment using hyperspectral imaging (HSI) of ischemia/reperfusion (IR) and analyzing the sildenafil effect.

Materials and Methods:

A one-sided hindlimb ischemia (120 minutes) followed by reperfusion (30 minutes) was created. Five mice received Sildenafil (1 mg/kg, i.p. twice before ischemia) and 5 mice served as control. The StO_2 at T0, 5, 30, 60, 120 minutes after ischemia (T5, 30, 60, 120) and 5, 15, and 30 minutes after reperfusion (T125, 135, 150) were measured through HSI.

Results:

The control group showed a significantly lower StO_2 at T120 (24.8% ± 17%) as compared with T0 (53.3% ± 7.04%) ($P = .013$) and T150 (76.8 ± 3.77; $P = .0008$). T150 showed a statistically significantly higher StO_2 than T0 ($P = .0134$). In the sildenafil group, T120 StO_2 (28.6% ± 20%) was lower than T0 (63.3% ± 8.46%; $P = .0312$) and T150 (73.3% ± 19.1%, $P = .0075$). The StO_2 values did not differ statistically between sildenafil and control groups.

Conclusions:

HSI is a feasible tool to quantify both ischemia and reperfusion phases during lower limb IR. Preconditioning with sildenafil did not modify IR-related StO_2 changes.

Perfusion imaging

Fast, non-invasive hyperspectral imaging tool for the diagnosis and management of complex foot and leg ulcers — part 1

(DOI: ./.)

Probst A

2020

The Diabetic Foot Journal

This is the first of two articles examining a new hyperspectral imaging system (HSI).

This non-invasive imaging system provides information about tissue oxygenation, tissue haemoglobin index, near-infrared and the tissue water index. The TIVITA® is a new compact camera that can be used in clinical practice by the patient's bedside. The data are generated within 6.4 seconds and the pictures can be shown to the patient directly at the bedside, enabling the clinician to discuss the findings with the patient, as well as possible treatment options.

Part one shows how HSI can be used to increase the patient's adherence to treatment. Part two will provide a more extensive look at how HSI works and how it can be used to evaluate and monitor wound dressing, debridement and new technologies in the treatment of diabetic foot ulcers and other chronic wounds.

Perfusion imaging

Hyperspectral imaging for bedside microcirculatory monitoring of critical care and perioperative patients: A new approach for tissue perfusion-based haemodynamic management?

(DOI: 10.1016/j.accpm.2019.11.004)

Dietrich M, Marx S, Weigand MA, Brenner T, Schmidt K

2020

Anaesthesia Critical Care & Pain Medicine

No abstract available

Perfusion imaging

Extended Perfusion Parameter Estimation from Hyperspectral Imaging Data for Bedside Diagnostic in Medicine

(DOI: 10.3390/molecules24224164)

Marotz J, Kulcke A, Siemers F, Cruz D, Aljowder A, Promny D, Daeschlein G, Wild

2019

Molecules

Background

Hyperspectral Imaging (HSI) has a high potential to be established as a new contact-free measuring method in medicine. Hyperspectral cameras and data processing have to fulfill requirements concerning practicability and validity to be integrated in clinical routine processes.

Methods

Calculating physiological parameters with high clinical value from the recorded remission spectra is a complex challenge. We present a data processing of HSI remission spectra based on a 5-layer model of perfused tissue that generates perfusion parameters for every layer and presents them as depth profiles. The modelling of the radiation transport and the solution of the inverse problem is based on familiar approximations but uses partially heuristic methods to be efficient and to fulfill practical clinical requirements.

Results

The parameter determination process is consistent as the measured spectrum is practically completely reproducible by the modelling sequence - that means, the whole spectral information is transformed into model parameters easily accessible for physiological interpretation. The method is flexible enough to be applicable on a wide spectrum of skin and wounds. Examples for advanced procedures utilizing the extended perfusion representation in clinical application areas (flap control, burn diagnosis) are presented.

Evaluation of peripheral artery disease with the TIVITA® Tissue hyperspectral imaging camera system

(DOI: 10.3233/CH-199215)

Grambow E, Dau M, Sandkühler N A, Leuchter M, Holmer A, Klar E, Weinrich M

2019

Clinical Hemorheology and Microcirculation

Background:

Objective, reliable and easy screening for peripheral artery disease (PAD) is essential to confirm the diagnosis and initiate the respective treatment. Therefore, a new non-invasive hyperspectral camera (TIVITA ® Tissue) was tested in patients with and without PAD.

Objective:

It was hypothesized that the oxygenation parameters of the TIVITA® Tissue correlate to established modalities for detection of PAD and allow differentiation between individuals with and without PAD.

Methods:

Evaluation of tissue oxygenation was performed in the angiosome of the medial plantar artery in 25 healthy young people and in 24 patients with and 25 patients without PAD in comparable age. Thereby, superficial oxygenation (StO_2) and near-infrared (NIR) perfusion index were measured with the TIVITA® Tissue. Additionally, the ankle-brachial-index (ABI), the complaint free walking distance and the vascular quality of life were assessed and demographic data were obtained from all participants.

Results:

TIVITA® Tissue analysis revealed significantly reduced StO_2 and NIR perfusion index in PAD compared to healthy young participants and patients without PAD. StO_2 and NIR perfusion index positively correlated with ABI, the complaint free walking distance and the vascular quality of life score.

Conclusions:

In summary, this new hyperspectral imaging camera bears great potential for PAD screening as well as for follow up.

Handnaht v. Stapler-Anastomose – Hyperspektralbetrachtung der Perfusion

(DOI: 10.1055/s-0039-1695191)

Jansen-Winkeln B, Takoh J P, Rabe S M, Chalopin C, Gockel I, Köhler H

2019

Zeitschrift für Gastroenterologie

Einleitung:

Klinisch sind die Handanastomose und die Stapleranastomose feste Bestandteile der Viszeralchirurgie. In Regionen wie dem kleinen Becken sind Stapleranastomosen die Regel. Bei Anastomosen in gut zugänglichen Regionen (Ileostoma-Rückverlagerung/Hemikolektomie rechts, etc) sind beide Verfahren möglich. Klinische Studien haben mehrfach bestätigt, dass beide Verfahren von der Anastomosenheilung gleichwertig sind. Dennoch gibt es bei beiden Verfahren strukturelle Unterschiede und Besonderheiten, deren Kenntnis für eine erfolgreiche Anastomose hilfreich ist.

Ziele:

In dieser Arbeit werden die Unterschiede der verschiedenen Anastomosentechniken zwischen Handnaht und Staplernaht bezüglich der Perfusion untersucht und dargestellt.

Material und Methoden:

Wir haben 30 konsekutive Anastomosen in zwei Gruppen (je 15 Patienten) intraoperativ mit der Hyperspektralkamera untersucht – Seit-zu-Seit-Stapler-Anastomose und die End-zu-End–Handnahtanastomose jeweils am Ileum. Die Hyperspektralkamera kann Licht im nicht-sichtbaren Bereich aufzeichnen und so durch spezifische und validierte Reflexionsmuster im Nah-Infraroten Bereich z. B. die Perfusion und Sauerstoffsättigung in oberflächlichen Schichten, in tieferen Schichten oder die Hämoglobinkonzentration darstellen. Zur Auswertung bestimmten wir die jeweiligen Parameter in einem Areal jeweils 5 mm um die Anastomose herum. Um technische Fehler auszuschließen, haben wir den klinischen Verlauf ausgewertet und nur unkomplizierte Verläufe eingeschlossen.

Ergebnisse:

Zwischen Handnaht und Stapler-Naht zeigen sich signifikante Unterschiede in der Perfusion. Die Region der Handnaht hatte eine schlechtere Perfusion und Sauerstoffsättigung als der Bereich um die Klammernaht ($p = 0{,}007$). Klinisch sind alle Anastomosen problemlos geheilt.

Schlussfolgerung:

Die intraoperative Hyperspektralbildgebung kann Unterschiede zwischen der Handnaht und der Klammernaht zeigen. Das Wissen und die durch das Nahtmaterial reduzierte Perfusion ist für den Chirurgen ein wichtiger Baustein.

Hyperspektralimaging demonstriert mikrozirkulatorische Effekte postoperativer Ergotherapie bei Patienten mit Morbus Dupuytren

(DOI: 10.1055/a-0916-8635)

Langner I, Sicher C, von Podewils S, Henning E, Kim S, Daeschlein G

2019

HaMiPla Handchirurgie, Mikrochirurgie, Plastische Chirurgie

Hintergrund

Der Morbus Dupuytren (MD) ist eine häufige Bindegewebserkrankung der Hand. Um ein Rezidiv nach Eingriff zu verhindern, erhalten die Patienten in der Regel eine frühzeitige postoperative Ergotherapie (ET). Der Einfluss dieser Maßnahme auf die Durchblutungssituation und damit auf das Auftreten oder Verhindern postoperativer Komplikationen ist jedoch nicht geklärt. Das Hyperspektralimaging (HSI) erlaubt die quantitative Beurteilung der Gewebsperfusion durch Messung der Sauerstoffsättigung und des Wassergehaltes des Gewebes.

Ziel

Evaluation der mikrozirkulatorischen Effekte der frühen postoperativen Ergotherapie nach partieller Fasziektomie bei MD mittels HSI zur Behandlungsoptimierung.

Patienten und Methode

Die Sauerstoffsättigung und der Wassergehalt des Gewebes der Hand wurden bei fünf Patienten vor und nach 20 Minuten standardisierter ET am ersten und zweiten postoperativen Tag mittels HSI evaluiert.

Ergebnisse

HSI zeigte eine qualitativ und quantitativ verbesserte Perfusion nach ET bei allen Patienten. Nach ET kam es zu einer Verbesserung der Sauerstoffsättigung um 20 % und zu einer Reduktion des Wassergehaltes um bis zu 17 %.

Schlussfolgerung

HSI erlaubt die schnelle und nicht-invasive Bestimmung einer verbesserten Sauerstoffversorgung und eines erniedrigten Wassergehaltes im Gewebe des OP-Gebietes bei Patienten nach partieller Fasziektomie bei MD als Folge der ET. Dies kann die Ursache für eine verbesserte Wundheilung und reduzierte Rezidivrate sein.

Perfusion imaging

A compact hyperspectral camera for measurement of perfusion parameters in medicine.

(DOI: 10.1515/bmt-2017-0145)

Kulcke A, Holmer A, Wahl P, Siemers F, Wild T, Daeschlein G

2018

Biomedizinische Technik/Biomedical Engineering

Worldwide, chronic wounds are still a major and increasing problem area in medicine with protracted suffering of patients and enormous costs. Beside conventional wound treatment, for instance kinds of oxygen therapy and cold plasma technology have been tested, providing an improvement in the perfusion of wounds and their healing potential, but these methods are unfortunately not sufficiently validated and accepted for clinical practice to date.

Using hyperspectral imaging technology in the visible (VIS) and near infrared (NIR) region with high spectral and spatial resolution, perfusion parameters of tissue and wounds can be determined. We present a new compact hyperspectral camera which can be used in clinical practice. From hyperspectral data the hemoglobin oxygenation (StO_2), the relative concentration of hemoglobin [tissue hemoglobin index (THI)] and the so-called NIR-perfusion index can be determined. The first two parameters are calculated from the VIS-part of the spectrum and represent the perfusion of superficial tissue layers, whereas the NIR-perfusion index is calculated from the NIR-part representing the perfusion in deeper layers. First clinical measurements of transplanted flaps and chronic ulcer wounds show, that the perfusion level can be determined quantitatively allowing sensitive evaluation and monitoring for an optimization of the wound treatment planning and for validation of new treatment methods.

Hyperspectral imaging for monitoring of perfusion failure upon microvascular anastomosis in the rat hind limb

(DOI: 10.1016/j.mvr.2017.10.005)

Grambow E, Dau M, Holmer A, Lipp V, Frerich B, Klar E, Vollmar B, Kämmerer P W

2018

Microvascular Research

Background/purpose:

Objective, reliable and easy monitoring of microvascular tissue perfusion is a goal that was achieved for many years with limited success. Therefore, a new non-invasive hyperspectral camera system (TIVITA™) was tested for this purpose in an *in vivo* animal model.

Methods:

Evaluation of tissue oxygenation during ischemia and upon reperfusion was performed in left hind limb in a rat model (n=20). Ischemia was induced by clamping and dissection of the superficial femoral artery. Reperfusion of the limb was achieved by microsurgical anastomosis of the dissected artery. Oxygenation parameters of the hind limb were assessed via TIVITA™ before and immediately after clamping and dissection of the artery, 3 and 30min after reperfusion as well as on postoperative days 1 and 2. Thereby, the non-operated hind limb served as control. As clinical parameters, the refill of the anastomosis as well as the progress of the affected leg were assessed.

Results:

In 12 from 20 cases, TIVITA™ recorded a sufficient reperfusion with oxygenation parameters comparable to baseline or control condition. However, in 8 from 20 cases oxygenation was found impaired after reperfusion causing a re-assessment of the microvascular anastomosis. Thereby, technical problems like stenosis or local thrombosis were found in all cases and were surgically treated leading to an increased tissue oxygenation.

Conclusions:

The TIVITA™ camera system is a valid non-invasive tool to assess tissue perfusion after microvascular anastomosis. As it safely shows problems in oxygenation, it allows the clinician a determined revision of the site in time in order to prevent prolonged ischemia.

The ability of hyperspectral imaging to detect perfusion disorders

(DOI: 10.1117/12.2286207)

Holmer A, Kämmerer P W, Dau M, Grambow E, Wahl P

2017

SPIE Proceedings

Blood perfusion as the supply of tissue with blood and therefore oxygen is a key factor in clinical practice. Especially in the field of flap surgery, a reduced perfusion of transplanted skin or operated areas is often cause of various complications. The success of microvascular reconstructions is directly related to the flap perfusion. The intraoperative and postoperative assessment of the anastomoses is of great importance in order to recognize possible complications at an early stage and to revise them in good time. Is the affected tissue located on the face, successful treatment and rapid healing is even more important since aesthetic aspects play a not insignificant role. A poor perfusion is often concealed, since methods are missing for an objective assessment of the perfusion status.

A method with increasing importance for clinical practice is given by hyperspectral imaging. We developed a new hyperspectral imaging system that can be used to observe tissue oxygenation and other tissue parameters and present the technical background and the parameter validation.

Perfusion imaging / Organ

Algorithm for Mapping Kidney Tissue Water Content during Normothermic Machine Perfusion Using Hyperspectral Imaging

(DOI: 10.3390/a13110289)

Markgraf W, Lilienthal J, Feistel P, Thiele C, Malberg H

2020

Algorithms

The preservation of kidneys using normothermic machine perfusion (NMP) prior to transplantation has the potential for predictive evaluation of organ quality. Investigations concerning the quantitative assessment of physiological tissue parameters and their dependence on organ function lack in this context.

In this study, hyperspectral imaging (HSI) in the wavelength range of 500–995 nm was conducted for the determination of tissue water content (TWC) in kidneys. The quantitative relationship between spectral data and the reference TWC values was established by partial least squares regression (PLSR). Different preprocessing methods were applied to investigate their influence on predicting the TWC of kidneys. In the full wavelength range, the best models for absorbance and reflectance spectra provided R_p^2 values of 0.968 and 0.963, as well as root-mean-square error of prediction (RMSEP) values of 2.016 and 2.155, respectively. Considering an optimal wavelength range (800–980 nm), the best model based on reflectance spectra (R_p^2 value of 0.941, RMSEP value of 3.202). Finally, the visualization of TWC distribution in all pixels of kidneys' HSI image was implemented.

The results show the feasibility of HSI for a non-invasively and accurate TWC prediction in kidneys, which could be used in the future to assess the quality of kidneys during the preservation period.

Perfusion imaging / Organ

Algorithms for mapping kidney tissue oxygenation during normothermic machine perfusion using hyperspectral imaging

(DOI: 10.1515/bmt-2017-0216)

Markgraf W, Feistel Ph, Thiele Ch, Malberg H

2018

Biomedical Engineering / Biomedizinische Technik

The lack of donor grafts is a severe problem in transplantation medicine. Hence, the improved preservation of existing and the usage of organs that were deemed untransplantable is as urgent as ever.

The development of novel preservation techniques has come into focus. A promising alternative to traditional cold storage is normothermic machine perfusion (NMP), which provides the benefit of improving the organs' viability and of assessing the organs' status under physiological conditions. For this purpose, methods for evaluating organ parameters have yet to be developed. In a previous study, we determined the tissue oxygen saturation (StO_2) of kidneys during NMP with hyperspectral imaging (HSI) based on a discrete wavelength (DW) algorithm.

The aim of the current study was to identify a more accurate algorithm for StO_2 calculation. A literature search revealed three candidates to test: a DW algorithm and two full spectral algorithms - area under a curve and partial least square regression (PLSR). After obtaining suitable calibration data to train each algorithm, they were evaluated during NMP. The wavelength range from 590 to 800 nm was found to be appropriate for analyzing StO_2 of kidneys during NMP. The PLSR method shows good results in analyzing the tissues' oxygen status in perfusion experiments.

Perfusion imaging / Organ

Oxygenation and perfusion monitoring with a hyperspectral camera system for chemical based tissue analysis of skin and organs

(DOI: 10.1088/0967-3334/37/11/2064)

Holmer A, Tetschke F, Marotz J, Malberg H, Markgraf W, Thiele C, Kulcke A

2016

Physiological Measurement

The monitoring of free flaps, free transplants or organs for transplantation still poses a problem in medicine. Available systems for the measurement of perfusion and oxygenation can only perform localized measurements and usually need contact with the tissue.

Contact free hyperspectral imaging and near-infrared spectroscopy (NIRS) for the analysis of tissue oxygenation and perfusion have been used in many scientific studies with good results. But up to now the clinical and scientific application of this technology has been hindered by the lack of hyperspectral measurement systems usable in clinical practice.

We will introduce the application of a new hyperspectral camera system for the quick and robust recording of remission spectra in the combined VIS and NIR spectral range with high spectral and spatial resolution. This new system can be applied for the clinical monitoring of free flaps and organs providing high quality oxygenation and perfusion images.

Perfusion imaging / Organ

Hyperspectral imaging for monitoring oxygen saturation levels during normothermic kidney perfusion

(DOI: 10.5194/jsss-5-313-2016)

Tetschke F, Markgraf W, Gransow M, Koch S, Thiele C, Kulcke A, Malberg H

2016

Journal of sensors and sensor systems

The development of improved preservation techniques and the reliable assessment of donor grafts are main fields of research in transplantation medicine.

Normothermic machine perfusion (NMP) is a promising alternative to static cold storage of organs, maintaining physiological conditions during preservation. In combination with NMP, we introduce hyperspectral imaging (HSI) as a novel approach for the monitoring of physiological kidney parameters. A line-scan HSI camera system was used to record images of porcine kidneys during NMP. Based on a dual-wavelength algorithm, the oxygen saturation levels were calculated from HSI recordings. Furthermore, we observed HSI images in the near-infrared (NIR) range in order to detect water characteristics of the kidney tissue. We found increasing levels of oxygenation during NMP and could discriminate between perfused and non-perfused areas. Cysts at the renal capsula were characterized by an absorption increase in the NIR band.

Within this work, we showed that HSI is able to detect relevant chemical changes during NMP and allows the identification of pathologic variations.

Perfusion imaging / Oxygenation

Hyperspectral imaging as a possible tool for visualization of changes in hemoglobin oxygenation in patients with deficient hemodynamics – proof of concept

(DOI: 10.1515/bmt-2017-0084)

Sicher C, Rutkowski R, Lutze S, von Podewils S, Wild T, Kretching M, Daeschlein G

2018

Biomedical Engineering / Biomedizinische Technik

There is a lack of imaging tools for the evaluation of spatial alterations in microcirculation including blood oxygen saturation and hemoglobin distribution but recent innovative developments in hyperspectral technology may offer a solution.

We examined different hemodynamic disorders in patients suffering from scleroderma, Dupuytren surgery, chronic foot ulcera and skin infections. Superficial and deeper blood oxygen saturation, hemoglobin distribution and water content were determined using hyperspectral imaging (HSI). In the patient with scleroderma, distinct cutaneous low perfused regions correlated with macroscopic skin aspects and seem to be potential therapy control marker. With HIS, accurate clinical evaluation of a macroscopic conspicuous wound after Dupuytren surgery was possible and influenced further surveillance decisions. HSI clearly revealed the spatial geometry and also the clinically related perfusion parameters of abscess formation and chronic ulcer wounds. The hemodynamically relevant parameters like blood oxygen saturation (1 mm to approx. 6 mm subcutaneous), total hemoglobin distribution and tissue water content can be easily determined and visualized with HSI in near real time.

Hence, this technique seems to be suitable for routine diagnostics of acute and chronic wounds as well as for the examination of systemic hemodynamic disturbances. Special indications may be transplant surveillance and monitoring of therapeutical interventions.

Perfusion imaging / Oxygenation

Analysis of tissue oxygenation in chronic leg ulcers by combination of a multi-spectral camera and a hyper-spectral probe

(DOI: ./.)

Zimmermann P, Scheibe A, Marotz J, Wollina U

2017

Georgian medical news

Objective evaluation of chronic wounds, such as leg ulcers, by the use of non-invasive techniques is of importance for diagnosis, monitoring treatment response, and probably leads to improved treatment strategies.

We performed a feasibility study for the combined use of a multi-spectral camera and a hyper-spectral probe to evaluate chronic leg ulcers with a focus on tissue oxygenation. Sixty patients - 40 females and 20 males were enrolled in the study. The age range was 46 to 85 years for males (mean 65.8 years, median 73.0 years) and 51 to 91 years for females (mean 74.4 years, median 77.0 years). Measurements were performed by hyper-spectral wound (HySkinII) probe and multi-spectral (DeMuk) camera on wounds and surrounding skin. The investigation results demonstrate a high variability of oxygenation within ulcers and the surrounding tissue. The methods allow an investigator to independently assess of tissue oxygenation in superficial and deeper layers.

Non-invasive multi- and hyper-spectral imaging techniques offer new opportunities of an objective assessment of chronic wounds.

Others

The molecular and physiological consequences of cold plasma treatment in murine skin and its barrier function

(DOI: 10.1016/j.freeradbiomed.2020.09.026)

Schmidt A, Liebelt G, Striesow J, Freund E, von Woedtke T, Wende K, Bekeschus S

2020

Free Radical Biology & Medicine

Cold plasma technology is an emerging tool facilitating the spatially controlled delivery of a multitude of reactive species (ROS) to the skin. While the therapeutic efficacy of plasma treatment has been observed in several types of diseases, the fundamental consequences of plasma-derived ROS on skin physiology remain unknown. We aimed to bridge this gap since the epidermal skin barrier and perfusion plays a vital role in health and disease by maintaining homeostasis and protecting from environmental damage.

The intact skin of SKH1 mice was plasma-treated in vivo. Gene and protein expression was analyzed utilizing transcriptomics, qPCR, and Western blot. Immunofluorescence aided the analysis of percutaneous skin penetration of curcumin. Tissue oxygenation, perfusion, hemoglobin, and water index was investigated using hyperspectral imaging. Reversed-phase liquid-chromatography/mass spectrometry was performed for the identification of changes in the lipid composition and oxidation. Transcriptomic analysis of plasma-treated skin revealed modulation of genes involved in regulating the junctional network (tight, adherence, and gap junctions), which was confirmed using qPCR, Western blot, and immunofluorescence imaging. Plasma treatment increased the disaggregation of cells in the stratum corneum (SC) concomitant with increased tissue oxygenation, gap junctional intercellular communication, and penetration of the model drug curcumin into the SC preceded by altered oxidation of skin lipids and their composition in vivo.

In summary, plasma-derived ROS modify the junctional network, which promoted tissue oxygenation, oxidation of SC-lipids, and restricted penetration of the model drug curcumin, implicating that plasma may provide a novel and sensitive tool of skin barrier regulation.

Others

Monte-Carlo Simulation of Light Tissue Interaction in Medical Hyperspectral Imaging Applications

(DOI: 10.1515/cdbme-2018-0067)

Herrmann B H, Hornberger C

2018

Current Directions in Biomedical Engineering

In Hyperspectral imaging (HSI) applications in medicine a uniform illumination is used and the illuminated surface is recorded with a camera with spectral resolution. Unlike in tissue reflectance spectroscopy with fixed light source - detector distances, in HSI the contribution of the influence of different tissue layers to the absorption signal is poorly understood. In this work a Monte-Carlo simulation is implemented which simulates the specific HSI illumination and detector geometry. A four-layer tissue model with variable blood volume fraction and oxygen saturation is used. With 5 % blood volume fraction and 75 % oxygen saturation, SaO2, of surrounding tissue, saturation changes in 1 mm and 2 mm deep layers lead to a change in remission of up to 3 % and up to 1 % respectively. Changes in deeper layers are hardly detectable. Further simulations will be focused on different tissue models as the depth resolution is expected to vary with tissue parameters like blood volume fraction.