





Review Article

Hyperspectral and multispectral imaging in neurosurgery: a systematic literature review and meta-analysis

Giulio Anichini^{a b 1}  , Maria Leiloglou^{c d 1}, Zepeng Hu^{c d}, Kevin O'Neill^{a b}, Daniel Elson^{c d}

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Abstract

Introduction

The neuro-surgical community is witnessing a rising interest for surgical application of multispectral/hyperspectral imaging. Several potential technical applications of this optical imaging are reported, but the set-up is variable and so are the processing methods. We present a systematic review of the relevant literature on the topic.

Materials and methods

A literature search based on the PRISMA principles was performed on PubMed, SCOPUS, and Web of Science, using MESH terms and Boolean operators. Papers regarding intra-operative in-vivo application of multispectral and/or hyperspectral imaging in humans during neurosurgical procedures were included. Papers reporting technologies related to radiological applications were excluded. A meta-analysis on the performance metrics was also conducted.

Results

Our search string retrieved 20 papers. The main applications of optical imaging during neurosurgery concern tumour detection and improvement of the extent of resection (15 papers) or visualization of perfusion changes during neuro-oncology or neuro-vascular surgery (5 papers). All the retrieved articles were pilot studies, proof of concepts, or case reports, with limited number of patients recruited. Sensitivity, specificity, and accuracy were promising in most of the reports, but the metanalysis showed heterogeneous approaches and results among studies.

Conclusions

The present review shows that several approaches are currently being tested to integrate hyperspectral imaging in neurosurgery, but most of the studies reported a limited pool of patients, with different approaches to data collection and analysis. Further studies on larger cohorts of patients are therefore desirable to fully explore the potential of this imaging technique.

Introduction

Hyperspectral imaging (HSI) and multispectral imaging (MSI) are non-invasive optical imaging technologies based on the spectral analysis of diffusely reflected light. They have both been extensively investigated in the field of general surgery [1], clinical diagnostic [2], pathology [3], and laboratory applications [4].

Two main features of HSI/MSI have been shown to potentially advance the surgical and clinical practice: 1) the possibility of identifying different types of tissues based on their optical properties; 2) the detection of areas of increased or decreased oxygen perfusion. Compared to different specialties, HSI/MSI have attracted less attention in neurosurgery, despite having the potential of changing the practice in different subspecialties, including neuro-oncology, neuro-vascular, epilepsy, trauma, skull base and spinal surgery.

The likely reason is that most of the investigated systems so far have not provided real-time visual output and have proven challenging to integrate with the existing neurosurgical toolkit. Moreover, most of the tested systems require a complex set-up, impeding the surgical workflow. State-of-the-art research focuses on the creation of a fully integrated, real-time system that would allow the neurosurgeons to use this technology in the routine clinical practice.

This work presents a systematic literature review on the in-vivo neurosurgical applications of MSI/HSI. The experience of different groups is critically discussed, with a particular interest in the different hardware systems and image processing approaches used, their pitfalls, and potential areas of improvement.

Section snippets

Technical overview

An elegant discussion regarding the physics of HSI/MSI is presented in previous reviews [5,6], and surgical applications have also been reviewed [7], so only a summary will be presented here. HSI/MSI is based on the physical principle of diffusely reflected light. Any visible object, including human tissue, interacts with light upon its illumination by light source, mainly via absorption and scattering. Some light is reflected to the observer: the fraction of the visible range that is detected...

Objectives

The purpose of the present work is to review the existing literature concerning the application of HSI/MSI in neurosurgery. The aim is to report the current state of this technology and its potential application as a standard neurosurgical tool to be used in every neurosurgical procedure. A meta-analysis of the technology's diagnostic performance is performed with the aim of comparing the results with the state-of-the-art standards set by other imaging approaches....

Inclusion and exclusion criteria

The rationale of the present search was to focus on intra-operative HSI/MSI technologies that could be

integrated with the neuro-surgical toolkit during procedures on human patients. For this reason, studies regarding the application of HSI/MSI imaging in neurosurgery have been selected on the bases of being in-vivo, intra-operative, and on human subjects. Studies on confocal microscopy, Raman spectroscopy, optoacoustic/photoacoustic spectral analysis, or fluorescent agents have been excluded...

Results

The PRISMA flowchart for the present review is illustrated in Fig.2. No automation tools were used for the present review. The PubMed search retrieved 39 papers; further screening selected 30 articles. The Scopus research retrieved 54 papers. Title screening selected three more papers, removing the duplicates of those already found with the PubMed research and those papers using different technologies and/or animals. Finally, the Web of Science research retrieved 51 papers. After duplicates...

Discussion

The present review analysed a total of 20 studies, 15 of which focused on testing HSI/MSI as a tool to refine the intra-operative identification of brain tumours, 5 focused on the detection of haemodynamic changes in the brain during different procedures. Although the technology looked very promising and the reported results were significant in most cases, several challenges and limitations emerged from the updated literature analysis....

Conclusions

Multispectral and hyperspectral imaging are promising tools that have shown the potential to be integrated into the neurosurgical toolkit for both tumour resection and detection of haemodynamic changes. However, the present review shows that the technology is still not real time, and that the image analysis process needs to be more homogeneous. The hardware requires more standardized implementation, with a faster set-up, and to become more user friendly, whereas reliable software with built-in...

CRedit authorship contribution statement

Giulio Anichini: Conceptualization, Methodology, Data curation, Writing – original draft, Writing – review & editing, Visualization. **Maria Leiloglou:** Conceptualization, Methodology, Data curation, Formal analysis, Writing – original draft, Writing – review & editing. **Zepeng Hu:** Data curation, Formal analysis, Validation, Writing – original draft. **Kevin O'Neill:** Writing – review & editing, Supervision. **Daniel Elson:** Validation, Writing – review & editing, Supervision, Project administration....

Declaration of competing interest

None....

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References (32)

W. Liu

[Acomparative performance analysis of multispectral and rgb imaging on her2 status evaluation for the prediction of breast cancer prognosis](#)

Translational Oncology (2016)

N.T. Clancy

[Surgical spectral imaging](#)

Med Image Anal (2020)

T.H. Tate

Multispectral fluorescence imaging of human ovarian and fallopian tube tissue for early-stage cancer detection

J Biomed Opt (2016)

G.B. Christensen

Clinical performance of a novel hyperspectral imaging device for cutaneous melanoma and pigmented skin lesions in Caucasian skin

Skin Res Technol (2021)

E.L. Spaeth *et al.*

Quantitative multispectral analysis following fluorescent tissue transplant for visualization of cell origins, types, and interactions

JoVE (2013)

J. Shapey

Intraoperative multispectral and hyperspectral label-free imaging: a systematic review of invivo clinical studies

J Biophot (2019)

G. Lu *et al.*

Medical hyperspectral imaging: a review

J Biomed Opt (2014)

H. Fabelo

Spatio-spectral classification of hyperspectral images for brain cancer detection during surgical operations

PLoS One (2018)

G.H. Bearman *et al.*

Spectral imaging: instrumentation, applications, and analysis III
(2005)

R. Lazcano

Parallel implementations assessment of a spatial-spectral classifier for hyperspectral clinical applications

IEEE Access (2019)



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Cited by (0)

- 1 First co-authors.

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