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Review

A systematic review of near-infrared spectroscopy in flap monitoring: Current basic and clinical evidence and prospects



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KEYWORDS

Near-infrared spectroscopy;
Flap monitoring;
Systematic review;
Tissue oxygen saturation;
Hemoglobin concentration

Summary Background: Near-infrared spectroscopy (NIRS) has been reported to be a reliable non-invasive modality for free flap monitoring; however, the history of its application in flap monitoring is short, and there is no definite consensus regarding its use at present.

Objectives: The aim of this review is to clarify the evidence related to post-operative flap monitoring using NIRS and examine its appropriateness and usability.

Materials and methods: The PubMed and Web of Science databases were searched using the strings “flap monitoring AND near-infrared spectroscopy” and “flap monitoring AND tissue oxygen saturation,” with a study period from inception to December 31, 2016. Two authors independently extracted articles and assessed the quality of the studies. Articles related to NIRS for flap perfusion monitoring were classified and selected regardless of study type.

Results: A total of 15 clinical studies and 8 animal studies were identified and reviewed. The evidence and information on various aspects of NIRS flap monitoring were summarized. The overall flap success rate was 99.5%, and the flap salvage rate was 91.1%, when measuring StO₂ at intervals of every 2 h or sooner. Single StO₂ monitoring was able to detect vascular compromise with 99.1% sensitivity and 99.9% specificity, and earlier than other monitoring methods, but additional Hb concentration monitoring was useful for avoiding false negatives and differentiating arterial and venous occlusion.

Conclusions: NIRS can be used for flap monitoring and displays high accuracy in various situations; however, further studies are needed to take full advantage of the potential of NIRS.

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Background / Objectives

Near-infrared spectroscopy (NIRS), first introduced in 1977 by Jobsis,¹ is a tool that allows for the non-invasive measurement of tissue components, and various experimental and clinical studies using NIRS to study tissue perfusion and oxygenation have been reported in many fields.

Recently, NIRS has been reported to be a reliable diagnostic modality for free flap monitoring due to its ability to precisely detect decreases in flap perfusion, and several reviews^{2,3} for free flap monitoring have concluded that NIRS is one of the best free flap monitoring devices. However, several different NIRS instruments are available, and the history of the application of NIRS in free flap monitoring is relatively short, so no definite consensus on its application or precise cut-off values in actual clinical settings has yet been established.

The aim of this review is to clarify the currently available evidence related to post-operative flap monitoring using NIRS and to examine the appropriateness and usability of NIRS in flap perfusion monitoring. We also organized and provided information on NIRS for flap perfusion monitoring.

Materials and methods

We performed a systematic review to evaluate the current evidence regarding post- and intra-operative flap monitoring using NIRS with an electronic and manual search, and organized the current evidence and information on NIRS for flap perfusion monitoring. The present review was carried out and compiled according to the PRISMA Guidelines, 2009.⁴ Two authors (Yu Kagaya and Shimpei Miyamoto) independently searched the electronic databases 'PubMed' and 'Web of Science,' using the strings "flap monitoring AND

near-infrared spectroscopy" and "flap monitoring AND tissue oxygen saturation," for articles published from inception to December 31, 2016.

The articles were classified and selected by reviewing their titles and abstracts as well as the manuscript bodies, if needed. The search was limited to the English language. Publications were included in the review if they were related to flap perfusion monitoring by NIRS, regardless of whether they were animal or clinical studies. Publications were excluded if they were not published as a full-length article in a peer-reviewed journal (*i.e.*, commentary, letters) or if they did not include original data (*i.e.*, review articles). Articles that were not related to NIRS and those in which NIRS was used for purposes other than the evaluation of flap perfusion were excluded. Articles on NIRS-related devices (two-dimensional perfusion monitoring) were also excluded.

Finally the methodological qualities of the manuscripts were assessed using the methodological index for non-randomized studies (MINORS) quality score for clinical studies.⁵ MINORS assesses the methodologies of both non-comparative and comparative studies by 8 and 12 quality items, respectively (score 0–2, [0, not reported; 1, reported inadequately; 2, reported adequately]). Thus, the maximum MINORS score of a non-comparative study is 16, while that of a comparative study is 24. In this review, a score of ≤ 9 (<60%) was considered to reflect poor quality in non-comparative studies, while a score of ≤ 14 (<60% score) was considered to reflect poor quality in comparative studies. In the article of MINORS, the average results for random samples by 2 reviewers were 13.93/24 (58%) and 12.98/24 (54%), respectively; as such, the cut-off value of 60% can be considered above average.

No appropriate quantitative assessment index has been developed for animal studies; therefore, the methodological quality of the animal studies was assessed according to

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