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Opinion Article

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Advancing Surgery in Real-time Tumor Grading and Pathological Diagnosis Using NAD(P)H-Activated Fluorescent Probes

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DESCRIPTION

Intraoperative pathological diagnosis and tumor histological grading are crucial for guiding surgical procedures and treatment decisions. Conventional methods often require time-consuming tissue processing and staining, delaying critical decision-making. This study introduces a novel approach utilizing a Nicotinamide Adenine Dinucleotide Phosphate (NAD(P))H-activated fluorescent probe to enable rapid and real-time pathological assessment and tumor grading during surgery.

NAD(P)H is a coenzyme involved in various cellular processes, including energy metabolism and redox reactions. Its autofluorescence has been recognized as a valuable indicator of cellular viability and metabolic activity. Cancer cells exhibit altered metabolic pathways, resulting in distinct NAD(P)H fluorescence patterns that correlate with tumor grade.

To validate the probe's efficacy, a specialized imaging system is developed for intraoperative use. This system comprises a fluorescence microscope or endoscope equipped with appropriate excitation and emission filters. Real-time image acquisition and processing algorithms enable quick analysis and visualization of NAD(P)H fluorescence patterns. During surgery, the fluorescent probe is applied to the tissue surface or injected into the tumor region. Within minutes, the probe binds to NAD(P)H within the cells, leading to fluorescence activation. The imaging system captures fluorescence signals, and the resulting images provide insights into the metabolic activity of the tissue.

The intensity and distribution of NAD(P)H fluorescence reflect cellular viability, proliferation, and metabolic activity. Based on these patterns, trained pathologists can rapidly assess tissue health and identify cancerous regions. The real-time nature of the technique allows immediate decision-making regarding tissue resection and margin evaluation. Tumor grading, which assesses the degree of cellular differentiation and aggressiveness, is traditionally performed through time-consuming histopathological analysis. The NAD(P)H-activated probe offers an alternative by correlating fluorescence patterns with histological grades.

The NAD(P)H-activated fluorescent probe has the potential to revolutionize intraoperative decision-making. By providing rapid pathological diagnosis and tumor grading, surgeons can make informed choices about the extent of resection and postoperative treatment strategies. Ultimately, this approach may improve patient outcomes, reduce the need for follow-up surgeries, and contribute to personalized cancer care. The primary advantage of this approach is its ability to provide real-time information about tissue health and tumor characteristics during surgery. This immediate feedback allows surgeons to make informed decisions about the extent of resection and treatment strategies.

The probe's sensitivity to NAD(P)H and its specificity for cancerous cells are critical. Cross-reactivity with healthy tissue or interference from other cellular components could affect the accuracy of the diagnosis. While the approach aims to provide real-time information to surgeons, trained pathologists are still required to interpret the fluorescence patterns correctly. Ensuring that pathologists are familiar with this new approach is crucial. Incorporating the imaging system and probe application into the surgical workflow seamlessly might require adjustments and training for surgical teams.

The NAD(P)H-activated fluorescent probe presents an innovative solution for rapid intraoperative pathological diagnosis and tumor histological grading. By harnessing the metabolic activity of cancer cells, this approach offers real-time insights into tissue health and malignancy. While challenges exist, the potential benefits for patient care and surgical decision-making make this technique a promising avenue for further research and development in the field of oncology.