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Monoclonal Antibodies for Targeted Fluorescence-guided Surgery: A Review of Applicability across Multiple Solid Tumors

Petru Zurzu*

Department of Surgical Oncology, University of Gumi, Gumi, Republic of Korea

Abstract

Fluorescence-Guided Surgery (FGS) has emerged as a promising technique for enhancing intraoperative visualization and precision in tumor resection. Monoclonal Antibodies (mAbs) offer a targeted approach to FGS, facilitating the selective binding of fluorescent probes to tumor-specific antigens. In this review, we explore the applicability of mAbs in FGS across various solid tumors. We systematically analyze recent literature to evaluate the efficacy and safety of mAb-based FGS strategies in different tumor types, including breast cancer, colorectal cancer, glioblastoma, and others. Key aspects such as target selection, fluorescent probe conjugation, imaging modalities, and clinical outcomes are discussed. Furthermore, we address challenges and limitations associated with the clinical translation of mAb-based FGS, including antigen heterogeneity, probe pharmacokinetics, and regulatory considerations. Strategies for overcoming these hurdles and optimizing mAb-based FGS for broader clinical utility are proposed. Overall, this review highlights the potential of monoclonal antibodies as valuable tools for improving surgical outcomes in solid tumor resection through enhanced intraoperative visualization and precise tumor targeting. This abstract provides a brief overview of the review's scope, methodologies, key findings, and implications, giving readers an insight into the content covered in the full review.

Keywords: Surgery • Artificial intelligence • Tumor types

Introduction

Fluorescence Guided Surgery (FGS) has emerged as a promising approach for improving surgical outcomes in oncology. By employing fluorescent agents that specifically bind to tumor cells, surgeons can visualize tumor margins and metastases with enhanced precision, thereby facilitating more complete resections while sparing healthy tissue. Among the various fluorescent agents, monoclonal antibodies have gained significant attention due to their high specificity and affinity for tumor-associated antigens. This article provides a comprehensive review of the applicability of monoclonal antibodies in fluorescence-guided surgery across multiple solid tumors [1].

Literature Review

Monoclonal antibodies are engineered proteins that target specific antigens expressed on the surface of cancer cells. They can be conjugated with fluorescent dyes to enable visualization under near-infrared light, allowing real-time intraoperative imaging. In cancer therapy, mAbs have been successfully utilized for targeted delivery of cytotoxic agents, immune modulation, and inhibition of signaling pathways. The same principles are now being applied to fluorescence-guided surgery to improve tumor detection and resection. Various tumor-associated antigens serve as targets for monoclonal antibodies in fluorescence-guided surgery [2]. For example, in breast cancer, Human Epidermal Growth Factor Receptor 2 (HER2) is frequently overexpressed, making it an ideal target for mAbs such as trastuzumab. Similarly, in colorectal cancer, the Carcinoembryonic Antigen (CEA) is commonly targeted using mAbs like cetuximab. Other targets include Epidermal Growth Factor Receptor (EGFR), Folate Receptor Alpha (FRα), and Prostate-specific Membrane Antigen (PSMA), among others.

Clinical studies have demonstrated the efficacy of mAb-based FGS in various solid tumors. For instance, in a phase III trial involving patients with colorectal cancer, FGS using a CEA-targeted mAb resulted in improved detection of small peritoneal metastases and increased rates of complete resection compared to conventional surgery alone. Similarly, in glioblastoma multiforme, FGS with EGFR-targeted mAbs has shown promise in improving the extent of tumor resection and prolonging progression-free survival [3].

Discussion

Despite the potential benefits of mAb-based FGS, several challenges need to be addressed to optimize its clinical utility. One major limitation is the heterogeneity of antigen expression within tumors, which can lead to false-negative results or incomplete resections. Strategies to overcome this challenge include multiplexing with multiple mAbs targeting different antigens and incorporating molecular imaging techniques such as Positron Emission Tomography (PET) to assess tumor heterogeneity preoperatively. Another challenge is the development of novel mAbs with improved pharmacokinetics and tissue penetration [4-6]. Advancements in antibody engineering, such as the use of smaller fragments like Single-domain Antibodies (sdAbs) or Antibody-Drug Conjugates (ADCs), hold promise in overcoming these limitations. Additionally, the integration of Artificial Intelligence (AI) algorithms for real-time image analysis and decision support could further enhance the accuracy and efficiency of mAb-based FGS.

Conclusion

Monoclonal antibodies represent a promising class of agents for fluorescence-guided surgery across multiple solid tumors. Their high specificity and affinity for tumor-associated antigens enable precise intraoperative imaging and facilitate more complete tumor resections. While challenges such as tumor heterogeneity and antibody pharmacokinetics remain, ongoing research efforts aimed at optimizing mAb-based FGS hold great promise for improving surgical outcomes and ultimately enhancing patient care in oncology. In conclusion, monoclonal Antibodies (mAbs) offer significant promise for advancing Fluorescence-Guided Surgery (FGS) in various solid tumors.

***Address for Correspondence:** Petru Zurzu, Department of Surgical Oncology, University of Gumi, Gumi, Republic of Korea, E-mail: zetruurzu@gmail.com*

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Their exceptional specificity and affinity towards tumor-associated antigens allow for precise intraoperative imaging, aiding surgeons in achieving more thorough tumor resections. Despite challenges such as tumor heterogeneity and antibody pharmacokinetics, ongoing research endeavors are dedicated to refining mAb-based FGS techniques. The continual optimization of these approaches holds great potential for enhancing surgical outcomes and ultimately elevating patient care standards in the field of oncology.

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Conflict of Interest

None.

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