

A Review of Molecular Imaging Applications and Challenges in Robotic Precision Surgery

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Abstract

Background: Molecular imaging is transforming medical diagnostics by providing insights into diseases at the molecular and cellular levels. This field merges advanced imaging technologies with molecular probes to visualize and quantify specific molecular targets in real-time, offering significant potential to improve surgical interventions' precision and effectiveness, especially in robotic precision surgery. This review aims to thoroughly explore the applications and challenges of molecular imaging within this innovative surgical context.

Method: A comprehensive search was conducted across PubMed, Science Direct, Web of Science, and Google Scholar databases up to October 2023, employing various keyword combinations such as "Molecular Imaging," "Surgical Interventions," "Robotic Surgery," and "Robotic Precision Surgery." The search culminated in selecting 11 of the most recent and pertinent studies for inclusion in this review.

Results: Molecular imaging extends its utility from early diagnosis to therapy planning and implementation in precision surgery, enabling meticulous preoperative planning by offering detailed insights into tumor molecular characteristics. This enhances diagnostic precision, facilitating a more informed and targeted robotic surgical strategy. By visualizing specific molecular markers within tissues, molecular imaging allows for precise targeting of pathological sites, improving tumor resection accuracy while sparing healthy tissues. Its real-time capability delivers dynamic information during surgery, aiding surgeons in modifying their techniques in response to the changing molecular profile of tissues. Nonetheless, challenges such as spatial resolution limitations and safety concerns associated with molecular probes need addressing to refine molecular imaging's application in robotic precision surgery. Bridging the gap between medical device innovations and tracer-based molecular imaging strategies is essential for a holistic approach to precision surgery.

Conclusion: Integrating molecular imaging with robotic precision surgery represents a significant shift in surgical practices, offering real-time, high-resolution insights into molecular targets. This convergence promises to redefine the surgical field, enhancing patient outcomes and reducing procedural invasiveness. Overcoming current challenges remains imperative for its successful clinical adoption, with ongoing research and technological developments poised to usher in a new era of precision medicine and surgery.

Keywords: Molecular imaging, Surgical interventions, Robotic surgery, Robotic precision surgery

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