

Surgical Margin Analysis in Pancreatic Neuroendocrine Tumors

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DESCRIPTION

Pancreatic neuroendocrine tumors are a distinct group of neoplasms arising from the hormone-producing cells of the pancreas. Although they are less common than pancreatic adenocarcinomas, they exhibit a broad spectrum of biological behavior ranging from indolent to highly aggressive. Surgical resection remains the primary treatment modality for localized tumors, and complete removal of the tumor with negative surgical margins is a key determinant of long-term survival and recurrence-free outcomes. The assessment of surgical margins involves careful evaluation of the interface between the tumor and surrounding pancreatic tissue, vasculature, and adjacent structures. Surgical margin analysis is critical not only for prognostication but also for guiding the need for additional therapeutic interventions.

The surgical margin status in pancreatic neuroendocrine tumors is influenced by several factors, including tumor size, location, proximity to major vessels, and the extent of invasion into surrounding tissues. These tumors can arise in any part of the pancreas, including the head, body, or tail, and each location presents unique challenges in achieving clear margins. Tumors in the pancreatic head often abut the duodenum, common bile duct, and portal vein, complicating resection. Tumors in the tail are generally more amenable to distal pancreatectomy with clear margins but may involve the splenic vessels or adjacent retroperitoneal tissues. The pattern of tumor growth, whether expansile or infiltrative, also impacts the ability to achieve negative margins. Infiltrative tumors may extend microscopic projections beyond the visible tumor edge, increasing the risk of residual disease even after what appears to be complete resection.

Histopathological examination of surgical margins in pancreatic neuroendocrine tumors requires systematic processing of the resected specimen. The specimen is oriented to identify the pancreatic transection margin, retroperitoneal margin, and any vascular or lymphatic interfaces. Gross inspection helps identify areas of close tumor proximity to the margins, and targeted sections are submitted for microscopic examination. Tumor cells are evaluated for the presence of residual neoplastic tissue at the

cut edge, with particular attention to well-differentiated poorly differentiated components, as the latter are more likely to extend beyond the gross tumor boundary. The margin status is usually categorized as negative, indicating no tumor cells at the inked margin; positive, indicating tumor cells at the margin; or close, suggesting tumor cells within a defined distance of the margin, typically less than one millimeter. Each category carries distinct clinical implications.

Several studies have demonstrated that negative surgical margins are strongly associated with improved overall survival and lower recurrence rates in patients with pancreatic neuroendocrine tumors. Patients with positive margins often require closer postoperative surveillance and may benefit from adjuvant therapies in selected cases. Margin involvement is particularly prognostic in high-grade or poorly differentiated tumors, where even minimal residual disease can lead to early recurrence and metastatic spread. Conversely, low-grade tumors with microscopic margin involvement may exhibit a more indolent course, but careful long-term monitoring is still warranted.

This approach is especially valuable when tumors are located near critical structures such as the portal vein or superior mesenteric vessels, where additional resection carries significant surgical risk. Although frozen section analysis provides rapid information, it has limitations, including sampling error and interpretive challenges in distinguishing well-differentiated tumor cells from reactive or regenerative pancreatic tissue. Therefore, frozen section findings are typically confirmed by permanent paraffin-embedded sections for definitive margin status.

The complexity of pancreatic neuroendocrine tumors is further illustrated by their heterogeneity. Some tumors exhibit mixed cellular differentiation or focal areas of higher-grade transformation, which may not be apparent on gross examination. These regions often exhibit a higher likelihood of margin involvement, underscoring the importance of comprehensive sampling of the resection specimen. Tumor microenvironment features, including desmoplastic stroma, perineural invasion, and lymphovascular involvement, also influence margin status and should be evaluated carefully. Recognition of these patterns aids in anticipating potential sites

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of recurrence and informs decisions regarding the extent of surgical resection.

Lymph node evaluation is another critical component of surgical management, as nodal metastasis can affect both prognosis and recurrence patterns. While the presence of positive nodes does not define margin status, it highlights the need for meticulous examination of both primary tumor margins and regional lymphatic tissue. Comprehensive surgical planning aims to achieve negative margins while balancing preservation of pancreatic function and minimizing postoperative morbidity. Achieving this balance requires collaboration among surgical, pathological, and radiological teams, as well as careful consideration of patient-specific factors such as comorbidities and tumor biology.

CONCLUSION

Surgical margin analysis in pancreatic neuroendocrine tumors is a pivotal aspect of patient management, with direct implications

for prognosis, recurrence risk, and therapeutic planning. Accurate assessment requires careful gross examination, systematic histopathological evaluation, and, in selected cases, intraoperative and molecular adjuncts. Negative margins are strongly associated with favorable outcomes, whereas positive or close margins necessitate heightened vigilance and may guide adjuvant treatment strategies. The heterogeneous nature of these tumors, their variable growth patterns, and their potential for high-grade transformation underscore the importance of comprehensive margin evaluation. Advancements in imaging, molecular profiling, and intraoperative guidance hold promise for improving margin assessment, optimizing surgical outcomes, and ultimately enhancing the long-term care of patients with pancreatic neuroendocrine tumors.