

The Evolving Cornerstone of Surgical Oncology

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Introduction

Intraoperative frozen section analysis is a cornerstone of modern surgical pathology, providing crucial real-time diagnostic information that directly guides surgical management. A major review of studies focusing on central nervous system tumors confirms its high reliability, demonstrating a sensitivity of 94% and specificity of 99%.

[1]

This level of accuracy is essential for neurosurgeons making immediate decisions in the operating room. The utility of this technique extends across various oncological disciplines. For instance, in gynecologic surgery, frozen sections show a diagnostic accuracy of 95.8% for ovarian masses, proving highly effective in differentiating between benign and malignant tumors.

[2]

This distinction is critical for determining the appropriate extent of surgery. However, its reliability decreases with borderline tumors, signaling an area requiring significant pathologist caution. The diagnostic landscape is also dynamic, influenced by evolving pathological classifications. A notable example is in thyroid pathology, where the reclassification of certain tumors as Noninvasive Follicular Thyroid Neoplasm with Papillary-like Nuclear Features (NIFTP) has directly led to fewer intraoperative cancer diagnoses and consequently, more conservative surgical interventions.

[3]

This highlights how changes in pathology definitions can profoundly affect patient outcomes. Despite its strengths, the practice is not without its challenges. Gynecologic pathology, in particular, presents common pitfalls, such as the misinterpretation of benign conditions that mimic cancer and difficulties in accurately staging endometrial cancer.

[4]

Recognizing these potential diagnostic traps is vital for pathologists. To address some of these challenges and improve workflow, technology is playing an increasingly important role. Research has validated the use of whole-slide imaging, or digital pathology, for the primary diagnosis of frozen sections, showing over 99% agreement between digital images and traditional glass slides.

[5]

This validation supports the expansion of telepathology, allowing for remote expert consultation. The technique's value is further affirmed in breast cancer surgery, where its use for examining sentinel lymph nodes helps detect metastasis intra-

operatively with a low false-negative rate, often sparing patients from a second operation.

[6]

Similarly, in oral cavity cancer, frozen section analysis of surgical margins is a reliable tool for ensuring complete tumor removal, which is critical for reducing local recurrence.

[7]

It demonstrates high sensitivity and specificity in confirming that the tissue edges are clear of cancer. In thoracic surgery, an analysis of over 3,000 lung cancer cases confirmed an overall accuracy of 98.4%, supporting its role in guiding the surgical approach by reliably distinguishing between different types of carcinoma.

[8]

Even in notoriously difficult areas like soft tissue tumors, an 18-year review shows that while a precise final diagnosis is challenging, frozen section is invaluable for confirming malignancy and ensuring clear surgical margins, achieving 95% accuracy in this primary goal.

[9]

Finally, the successful large-scale implementation of a digital telepathology system for frozen sections at a major academic center, with a 98% diagnostic concordance rate, demonstrates that this technological shift is not just feasible but also highly reliable for urgent intraoperative diagnoses.

[10]

This progression paves the way for more flexible, efficient, and interconnected pathology services.

Description

Intraoperative frozen section is a rapid and powerful diagnostic tool that provides surgeons with critical information during an operation, profoundly influencing surgical strategy. Its high diagnostic accuracy is consistently demonstrated across a wide range of specialties. For example, in neurosurgery, a systematic review established its exceptional reliability for central nervous system tumors with 94% sensitivity and 99% specificity [1]. This accuracy is mirrored in other fields, such as thoracic surgery, where a large study on lung cancer cases reported an overall accuracy of 98.4%, effectively guiding surgeons in differentiating between tumor types [8]. In the management of ovarian masses, frozen section achieves a 95.8% accuracy rate, which is crucial for distinguishing benign from malignant lesions

and tailoring the surgical procedure accordingly [2]. Similarly, its application in breast cancer for evaluating sentinel lymph nodes is highly effective, allowing for immediate axillary lymph node dissection if metastasis is found, thus preventing the need for a second surgery [6].

One of the most critical applications of frozen section analysis is the assessment of surgical margins. The primary goal of many cancer surgeries is the complete removal of the tumor with a surrounding layer of healthy tissue, known as a clear margin. Frozen section is instrumental in achieving this outcome. In surgeries for oral cavity squamous cell carcinoma, it is used to check the edges of the removed tissue for any remaining cancer cells, a process that has been shown to have very high specificity (99%) and good sensitivity (81%), significantly reducing the risk of local cancer recurrence [7]. The same principle applies to complex soft tissue tumor surgeries. While obtaining a precise subtype diagnosis on a frozen section can be difficult, its main purpose—to confirm malignancy and ensure the surgical margins are free of tumor—is achieved with high accuracy (95%), validating its role in these challenging cases [9].

Despite its proven utility, the technique has recognized limitations and is subject to diagnostic pitfalls. Pathologists must be aware of these challenges to avoid misinterpretation. For instance, while highly accurate for clearly benign or malignant ovarian tumors, frozen sections are less reliable for diagnosing borderline ovarian tumors, a gray area that requires careful consideration [2, 4]. Gynecologic pathology, in general, presents several challenges, including benign conditions that can histologically mimic cancer and difficulties in the precise staging of endometrial cancer during surgery [4]. Furthermore, the field of pathology is constantly evolving. The reclassification of a subset of thyroid tumors to the less aggressive NIFTP category has directly impacted intraoperative diagnosis, leading to a decrease in cancerous diagnoses on frozen sections and a corresponding shift towards more limited, less aggressive surgeries [3]. This demonstrates how changes in diagnostic criteria directly translate to changes in patient management.

The future of intraoperative consultation is being shaped by technological advancements, particularly the adoption of digital pathology and telepathology. These technologies allow for the digitization of glass slides, enabling pathologists to view and diagnose cases remotely. The validation of whole-slide imaging for primary diagnosis of frozen sections, with a diagnostic concordance rate of over 99% compared to traditional microscopy, has been a pivotal step [5]. Building on this, large academic medical centers have successfully implemented digital telepathology systems for their frozen section services. These systems have proven to be reliable, with diagnostic agreement rates of 98%, and do not introduce significant delays [10]. This transition to digital workflows makes it possible for hospitals without an on-site pathologist to access expert consultation from anywhere, ultimately improving patient care and making pathology services more efficient and flexible.

Conclusion

Intraoperative frozen section analysis is a highly reliable and accurate diagnostic tool used across numerous surgical specialties to guide immediate decisions in the operating room. Studies confirm its high sensitivity and specificity for diagnosing tumors in the central nervous system, ovaries, lungs, and breast, where it is crucial for distinguishing between benign and malignant tissue and assessing the spread of cancer to lymph nodes. A primary application is the real-time evaluation of surgical margins in cancers of the oral cavity and soft tissues, which significantly helps in ensuring complete tumor removal and reducing the likelihood of recurrence. While the technique has its challenges, particularly with borderline ovarian tumors and other diagnostic pitfalls in gynecologic pathology, its overall value is undisputed. The field is also evolving; changes in pathological classifica-

tions, such as for thyroid tumors, directly impact surgical approaches and patient outcomes. Critically, the integration of digital pathology and telepathology is proving to be a safe and effective evolution of the practice. The validation of whole-slide imaging shows near-perfect agreement with traditional methods, enabling reliable remote diagnosis. This technological shift is making expert pathology consultation more accessible and improving the efficiency of surgical pathology services, solidifying the role of frozen section as an indispensable component of modern surgical oncology.

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Conflict of Interest

None.

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