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SHORT COMMUNICATION

The role of ultra-high frequency ultrasound (UHF-US) in the study of early stages of squamous cell carcinoma of the tongue

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Abstract

Purpose This study evaluates the prognostic value of ultra-high frequency ultrasonography (UHF-US) in assessing the depth of invasion (DOI) in early-stage tongue squamous cell carcinoma (OSCC). Given the limitations of traditional imaging techniques such as magnetic resonance (MRI) and computed tomography (CT), UHF-US offers a high-resolution alternative for preoperative DOI estimation.

Results UHF-US demonstrated in literature a high level of accuracy in preoperative DOI measurement, offering improved precision over MRI and CT. The study findings reinforce the clinical importance of DOI as a predictor of nodal metastasis risk and patient outcomes. UHF-US exhibited strong sensitivity and specificity, supporting its role as a valuable tool in guiding surgical decisions.

Conclusion The study confirms the prognostic significance of DOI in early-stage tongue OSCC and highlights UHF-US as a highly accurate imaging modality for preoperative DOI assessment. UHF-US could play a crucial role in surgical decision-making and patient selection for elective neck dissection. Further research will be needed to validate these findings and explore their practical application in the management of as many oral malignant lesions as possible.

Keywords Ultra-high frequency ultrasonography · Oral squamous cell carcinoma · Preoperative imaging · Elective neck dissection (END) · Staging

Ultrasonography has become an essential tool in modern medical imaging, offering a non-invasive, real-time, and high-resolution method for evaluating soft tissue structures. Over time, technological advancements have significantly improved the resolution and accuracy of ultrasound-based imaging, making it an invaluable tool in various medical specialties, including oncology [1]. Ultra-high frequency ultrasonography (UHF-US) is a recent development that provides enhanced spatial resolution, enabling precise visualization of superficial tissues [2]. This instrument uses probes with frequencies between 30 and 100 MHz It allows obtaining images with a resolution of up to 30 µm It can acquire images in depths of up to 3 cm It can acquire images at frame rates of up to 10,000 fps It provides information on blood flow, tissue movement, presence of molecular biomarkers, anatomy and dimensions of 2D, 3D and 4D regions This capability is particularly beneficial for assessing small and localized tumors, such as those found in the oral cavity.

The role of UHF-US in OSCC management

In the management of oral squamous cell carcinoma (OSCC), depth of invasion (DOI) is a crucial prognostic indicator, influencing the risk of nodal metastasis and overall patient outcomes [3]. Traditional imaging methods such as magnetic resonance imaging and computed tomography have been used for DOI assessment, but they have limitations in accurately differentiating tumor tissue from surrounding inflammation. UHF-US has emerged as an alternative

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imaging technique that overcomes these challenges, allowing for more precise preoperative DOI measurement and better-informed surgical planning. Moreover, early identification of aggressive tumor characteristics through UHF-US can support a more tailored treatment approach, minimizing unnecessary interventions while ensuring that high-risk patients receive appropriate care.

Advantages of UHF-US for preoperative imaging

One of the key advantages of UHF-US is its ability to provide real-time imaging of tumor margins, enabling more accurate tumor localization and assessment. The high spatial resolution of UHF-US allows clinicians to visualize small differences in tissue density and composition, improving diagnostic accuracy. This is particularly important in OSCC, where accurate DOI measurement can influence decisions regarding elective neck dissection (END) [4]. By identifying patients who are at higher risk for nodal metastasis, UHF-US helps optimize treatment strategies, reducing the likelihood of unnecessary surgery while ensuring appropriate management of high-risk individuals. Furthermore, its non-invasive nature allows for repeat examinations without the risks associated with radiation exposure, making it a valuable tool for longitudinal patient assessment.

Intraoperative and postoperative applications

Another important application of UHF-US is intraoperative assessment. During surgical resection, ensuring adequate tumor margins is critical to preventing recurrence and improving patient survival. UHF-US can be used in real time to evaluate surgical margins, allowing for immediate adjustments if necessary. This intraoperative capability enhances the precision of tumor excision, minimizing the need for additional procedures and improving overall patient outcomes [5].

The role of ultrasonography is not limited to preoperative evaluation. It is increasingly being recognized as a valuable tool for postoperative monitoring and long-term follow-up. UHF-US can be used to detect early signs of recurrence, assess treatment response, and guide additional interventions if necessary [6]. Its ability to provide detailed soft tissue imaging without the risks associated with radiation exposure makes it an ideal modality for longitudinal patient management. Additionally, the accessibility and ease of use of UHF-US make it particularly beneficial in resource-limited settings, where advanced imaging modalities such as MRI may not be readily available.

Comparison with MRI and CT

Compared to MRI and CT, UHF-US offers several advantages beyond resolution and accuracy. It does not require exposure to ionizing radiation, making it a safer option for repeated assessments [7]. Additionally, it does not necessitate the use of contrast agents, reducing the risk of adverse reactions in patients with renal impairment or allergies. The portability of ultrasound devices also allows for greater flexibility in clinical settings, enabling rapid and on-site evaluations that may not be feasible with traditional imaging modalities. These features make UHF-US an attractive alternative for both initial diagnostic evaluations and follow-up imaging, particularly in cases where patients may require ongoing surveillance for recurrence or disease progression.

Challenges and future directions

Despite its advantages, the successful implementation of UHF-US in clinical practice requires specialized training and experience. The accuracy of ultrasound-based imaging is highly operator-dependent, and variability in measurement techniques can affect reproducibility. Standardized imaging protocols and structured training programs are essential to ensure consistent results across different institutions. Additionally, further research is needed to refine the application of UHF-US in OSCC and explore its potential in other head and neck malignancies. Future studies should also investigate the integration of artificial intelligence (AI) and machine learning algorithms with UHF-US to enhance image interpretation and improve diagnostic consistency.

Beyond OSCC, the applications of UHF-US extend to other areas of oncology and general medicine. It has been explored in dermatology for assessing skin tumors, in ophthalmology for evaluating ocular lesions, and in vascular medicine for imaging superficial blood vessels. Its utility in evaluating musculoskeletal injuries and peripheral nerve conditions is also gaining recognition, expanding its role in various medical disciplines [7]. As technology continues to evolve, the potential uses of UHF-US will likely expand, leading to further advancements in medical diagnostics and treatment planning [8, 9].

Conclusion

In conclusion, UHF-US represents a significant advancement in the field of medical imaging, particularly in the assessment of superficial tumors such as OSCC. Its ability to provide high-resolution, real-time imaging makes it a valuable tool for preoperative evaluation, intraoperative guidance, and postoperative monitoring. By improving the accuracy of DOI measurement, UHF-US plays a critical role in optimizing patient management and surgical decision-making. While challenges related to training and standardization remain, ongoing research and technological improvements will continue to enhance the clinical utility of this imaging modality. The integration of UHF-US into routine oncologic care has the potential to improve diagnostic precision, reduce unnecessary interventions, and ultimately lead to better patient outcomes. The continued development of UHF-US technology, in combination with AI-driven analysis and image enhancement techniques, will further strengthen its role in personalized medicine and precision oncology, making it an indispensable tool in the future of cancer diagnosis and treatment.

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Declarations

Ethical approval This article does not contain any studies with human participants or animals performed by any of the authors. The treatment of the presented patient was not in any way influenced due to this article.

Conflict of interest The authors certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

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