



Color-Doppler ultrasound in the diagnosis of oral vascular anomalies – A review

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Abstract

Color Doppler ultrasonography (CDUS) is a valuable imaging modality for the diagnosis and management of oral vascular anomalies, providing both morphological and vascular information. Its noninvasive nature, real-time imaging capabilities, and ability to assess vascular flow patterns make it a useful tool in clinical practice. However, to maximize its utility, a multidisciplinary approach and close collaboration between imaging specialists and clinicians are essential. Future advancements, such as the integration of 3D and 4D imaging, machine learning, and artificial intelligence, hold promise for further improving the diagnostic accuracy of CDUS in this context. Additionally, standardized protocols, guidelines, and cost-effectiveness studies are needed to ensure the widespread adoption and effective use of the CDUS for the treatment of oral vasculature.

Keywords: Color doppler ultrasonography, oral vascular anomalies, recent advancement, doppler shift

Introduction

A vascular lesion is an encompassing term used to describe a vast range of conditions comprises of an atypical number, structure, or position of blood vessels [1]. Vascular malignancies were modified from vascular impairment by their clinical appearance, radiological and pathological features, and biological behaviour [2] Recently, colour Doppler ultrasonography (CD-USG) has been used for detecting blood flow signals in vessels of malignant tumors by means of uninterrupted pulsed-wave Doppler and colour flow mapping techniques [3]. Various treating methods were proposed including primary surgical resection, cryotherapy, embolization, sclerotherapy, laser treatment and steroids [4]. The aim of this study is to emphasize that the colour-Doppler ultrasound may be an crucial method for obtaining diagnostic images that can distinguish between the vascular abnormalities found in the mouth cavity.

Principles of Color Doppler Ultrasonography

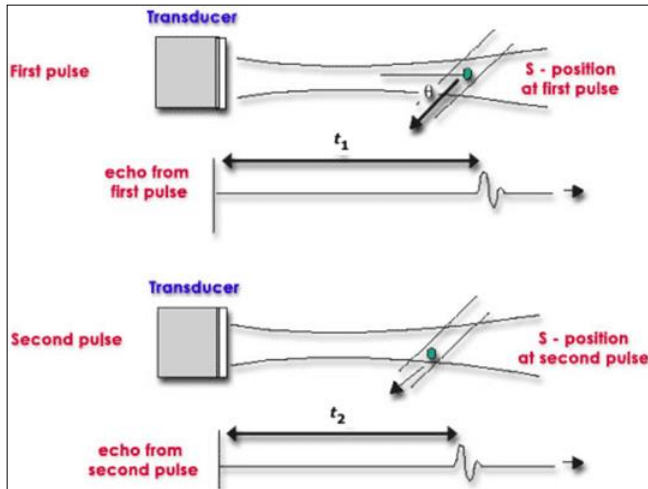
Standard ultrasonic pulse-echo (PE) imaging generates anatomical cross-sectional profiles of the body. In the incident of ultrasound colour flow imaging (CFI) (known also as colour Doppler imaging), a colour map representing movement is superimposed on the PEimage. The method has many functions but is mainly used to image blood flow, and a lesser intensity to the flow of the cardiac muscle. In principle, CFI techniques are similar to PE techniques in which information regarding the location of each objective in the body, analogous to each pixel in the image, is derived

in the same way, i.e. from a knowledge of ultrasonic beam direction and pulse round-trip transit time, but the rebounding echoes are scrutinized in terms of Doppler shift instead of amplitude. Although the technique is often stated as a Doppler technique, it does not make use of the Doppler shift on each transmitted pulse but rather generates estimates of velocity from the phase shifts or time respite amidst the echoes from the similar sample volume during successive pulses. A rate of shift in an aspect can be interpreted as a frequency shift and the velocity of the objective can be determined from this frequency shift using the same equation that is used to interpret the accurate Doppler shift found in continuous wave ultrasound instruments, i.e.

$$fd = 2ftvl\cos\theta/c$$

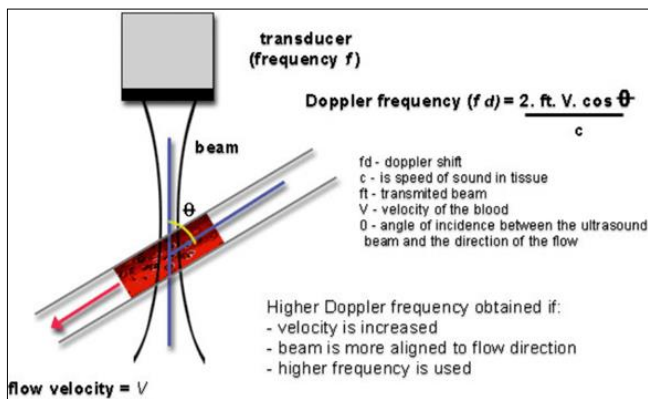
where fd is the Doppler shift frequency, θ is the angle between the ultrasound beam and flow vector, $lv\cos\theta$ is the component of the velocity of the target towards the transducer, f_t is the transmitted ultrasound frequency and c is the velocity of ultrasound in the tissue.

Note hence in the standard CFI applications, it is the integral part of the velocity of target towards the transducer that is measured and therefore supplementary knowledge about the direction of flow is necessary if the velocity vector is to be quantified in terms of magnitude and direction [5]. Figures 1 and 2 demonstrate that motion must be in the direction of the beam in order for there to be relative motion from pulse to pulse if the flow is perpendicular to the beam.



Pic courtesy: Hecher, K., Ville, Y., Snijders, R., & Nicolaides, K. (1995, May). Doppler studies of the fetal circulation in twin–twin transfusion syndrome. *Ultrasound in Obstetrics &Gynecology*, 5(5), 318–324. <https://doi.org/10.1046/j.1469-0705.1995.05050318.x>

Fig 1: Measurement of ultrasound velocity. A scatterer S with a beam/flow angle and a velocity V is depicted in the diagram. As the scatterer travels across the beam, the difference in transmit-to-receive time (t2) between the first and second pulses can be used to compute the velocity



Pic courtesy: Hecher, K., Ville, Y., Snijders, R., & Nicolaides, K. (1995, May). Doppler studies of the fetal circulation in twin–twin transfusion syndrome. *Ultrasound in Obstetrics &Gynecology*, 5(5), 318–324. <https://doi.org/10.1046/j.1469-0705.1995.05050318.x>

Fig 2: Ultrasound Doppler. The movement of the scatterers across the beam is measured by Doppler ultrasonography as a phase shift in the signal that is received. If the beam/flow angle is known, the resulting Doppler frequency can be utilized to calculate velocity

Mechanism of Action [6]

Color flow Doppler avoids the range ambiguity of continuous wave Doppler (CWD) by using intermittent sampling of ultrasonic waves, much like pulsed wave Doppler (PWD). In contrast, Color Flow Doppler simultaneously examines multiple sample volumes (each pixel denoting a sample volume) along an array of scan lines. Pulsed wave Doppler, on the other hand, is restricted to the interrogation of flow velocity and direction along a single line at a specific depth (defined by the sample volume or gate).

The flow velocity and direction data are randomly color-coded and projected onto an M-mode, or grayscale, image. Flow toward the transducer (positive Doppler shift) is shown in red, and flow away from the transducer (negative

Doppler shift) is shown in blue with lighter shades of each color denoting higher velocities. A third hue, typically yellow or green, is frequently used to indicate regions with high flow turbulence. These colors can be defined by the user and even reversed, however, this is usually not a good idea as it could confuse readers of the photos in the future.

However, aliasing shares a constraint with pulsed wave Doppler in that when the Nyquist limit is reached, the apparent flow direction occurs in the opposite direction of the actual flow. The depth at which flow is insonated and the transducer being employed have an additional influence on the velocity at which flow aliases.

The colour quickly changes from red to blue or from blue to red when the Nyquist limit is reached.

In areas of turbulent flow, there are noticeable changes in velocity, which results in a "mosaic" pattern of colours.

The aliasing and "mosaic colours" phenomena allow for accurate jet delineation and PISA measurement.

Similar to PW Doppler, the imaging depth and the ultrasonic frequency being used determine the Nyquist limit, or the velocity at which aliasing happens.

The pulse repetition frequency (PRF) can be changed to modify the Nyquist limit (within a given range) [7].



Pic courtesy: Nayyar, A., Gandhi, R., Bhowate, R., Gandhi, S., & Dongerwar, G. (2015). Color Doppler ultrasonography in oral squamous cell carcinoma: Making ultrasonography more meaningful. *Clinical Cancer Investigation Journal*, 4(5), 595. <https://doi.org/10.4103/2278-0513.164723>

Fig 3: Color Doppler Ultrasound Machine

Applications

Vascular Lesions: CDUS can help differentiate between different types of vascular lesions such as hemangiomas, vascular malformations, and varices. It can also assess the extent and vascularity of these lesions.

Salivary Gland Lesions: CDUS can be used to evaluate salivary gland lesions such as sialadenitis, salivary gland tumors, and cysts. It can help assess the vascularity and size of these lesions.

Inflammatory Lesions: CDUS can aid in the evaluation of inflammatory lesions such as abscesses and cellulitis by assessing the vascularity and extent of inflammation.

Benign and Malignant Tumors: CDUS can be used to differentiate between benign and malignant tumors in the oral cavity. It can help assess the vascularity of the tumor, which can be indicative of its aggressiveness.

Lymphadenopathy: CDUS can be used to evaluate enlarged lymph nodes in the neck, which may be associated with oral lesions or systemic diseases. It can help assess the vascularity and morphology of the lymph nodes.

Advancements and Future Direction

- 1. Integration of 3D and 4D Imaging:** The integration of 3D and 4D imaging techniques with CDUS could provide a more detailed assessment of oral vascular anomalies, allowing for better characterization and treatment planning.
- 2. Machine Learning and Artificial Intelligence:** The use of machine learning and artificial intelligence algorithms could enhance the diagnostic accuracy of CDUS for oral vascular anomalies, potentially leading to more personalized treatment approaches.
- 3. Enhanced Visualization Techniques:** Continued advancements in visualization techniques, such as contrast-enhanced CDUS, could improve the detection and characterization of oral vascular anomalies, particularly in cases where traditional CDUS may be limited^[8].
- 4. Telemedicine and Remote Monitoring:** The integration of CDUS into telemedicine platforms could allow for remote monitoring of oral vascular anomalies, enabling timely interventions and reducing the need for in-person visits.
- 5. Standardization and Guidelines:** Developing standardized protocols and guidelines for the use of CDUS in the diagnosis and management of oral vascular anomalies could improve consistency and outcomes across different healthcare settings^[9].
- 6. Patient-Centered Outcomes Research:** Future research should focus on evaluating patient-centered outcomes, such as quality of life and patient satisfaction, to assess the impact of CDUS in the management of oral vascular anomalies^[10].
- 7. Cost-Effectiveness Studies:** Further studies are needed to evaluate the cost-effectiveness of CDUS compared to other imaging modalities in the diagnosis and management of oral vascular anomalies, taking into account both direct and indirect costs.

- 8. Education and Training:** Continued education and training programs for healthcare providers on the use of CDUS for oral vascular anomalies could improve its widespread adoption and ensure its safe and effective use.

Conclusion

In conclusion, color Doppler ultrasonography (CDUS) is a valuable imaging modality for the diagnosis of oral vascular anomalies, providing both morphological and vascular information. Its non-invasive nature, real-time imaging capabilities, and ability to assess vascular flow patterns make it a useful tool in clinical practice. However, to maximize its utility, a multidisciplinary approach and close collaboration between imaging specialists and clinicians are essential. Future advancements, such as the integration of 3D and 4D imaging, machine learning, and artificial intelligence, hold promise for further improving the diagnostic accuracy of CDUS in this context. Additionally, standardized protocols, guidelines, and cost-effectiveness studies are needed to ensure the widespread and effective use of CDUS in the diagnosis and management of oral vascular anomalies. Overall, CDUS represents a valuable addition to the armamentarium of imaging modalities available for evaluating oral vascular lesions.

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