Article
JOURNAL OF UNIVERSITY OF BABYLON
For Pure and Applied Sciences (JUBPAS)
Vol.33; No.1.| 2025

ISSN: 2312-8135 | Print ISSN: 1992-0652

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Understanding the Physical Principles of Doppler Ultrasound

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فهم المبادئ الفيزيائية للموجات فوق الصوتية دوبلر

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Accepted: 1/2/2025 **Published:** 31/3/2025

ABSTRACT

Background

The results showed that Grey Doppler and Color Doppler produce very different images and cannot diagnose the same things. Color Doppler ultrasound captures changes in blood flow more clearly and accurately than grayscale imaging, enabling doctors to diagnose artery problems more accurately. Both types of medical imaging showed the anatomy, blood flow patterns in the cyst, and arterial dilatation correctly.

Materials and Method

The Doppler examination is performed in the same way as a regular ultrasound, where after applying the gel to the area with a deep pen diluted on the area, the ultrasound examiner moves it or moves it until the doctor detects the signal well. It should start to move less noticeably, and then sounds that represent blood flow in the blood vessels are heard.

Results

The study found that Grey Doppler and Colour Doppler performed differently in problem diagnosis and photo quality. Colour Doppler ultrasonography displayed blood flow dynamics more accurately and precisely than greyscale imaging, enabling more accurate vascular abnormality detection. In medical imaging, both modalities precisely reconstruct anatomical features, cyst blood flow patterns, and artery dilations. Color Doppler ultrasound's clarity and detail in monitoring blood flow distribution in vessels improved the diagnosis's accuracy.

Conclusions

Using physical technology to enhance the accuracy and understanding of medical images, Doppler ultrasound has been investigated in advanced clinical settings such as diagnosing cardiovascular disorders and has been found to be highly accurate in diagnosis.

Keyword: Ultrasound; imaging Doppler; color Doppler; blood vessels; medical imaging

INTRODUCTION

In the field of physics, the term "ultrasound" encompasses any forms of acoustic radiation that possess a frequency surpassing the range of human hearing, specifically 20,000 hertz or 20 kilohertz. Diagnostic sonographic scanners commonly function within the frequency spectrum spanning from 2 to 18 megahertz, which exceeds the human auditory threshold by several orders of magnitude. Sonograms with fewer features can be generated by utilizing higher frequencies, which are associated with shorter wavelengths. Diagnostic sonography, often known as ultrasonography, is a diagnostic imaging technique that uses ultrasound to examine various subcutaneous body structures such as tendons, muscles, joints, arteries, and internal organs. Its primary purpose is to identify potential pathology or lesions within these structures. Sonography is a highly efficient method for visualizing inner layers of the body. Sonographers commonly employ a portable probe, known as a transducer, which is positioned directly on the patient and manipulated. A gel composed of water is employed to establish a connection between the ultrasonic transducer and the patient [1,2]. Despite being discovered 12 years before to the invention of X-rays in 1883, ultrasonography was not widely utilized in medical until considerably later. Ultrasound's initial practical implementation was documented during World War I for the purpose of locating submarines. The utilization of ultrasound in the field of medicine commenced throughout the 1950s. The concept was initially developed in the field of obstetrics, and subsequently expanded to encompass several areas of medicine, including general abdominal diagnostics, pelvic diagnostics, cardiology, ophthalmology, orthopedics, and others [3]. Ultrasound is highly valuable in clinical settings due to its noninvasive nature, excellent imaging capabilities, and ease of use [4,5]. The Doppler mode utilizes the Doppler effect to measure and visualize blood flow. Cannula sonography has a significant function in the field of medicine. Doppler measurements can be used to improve sonography by utilizing the Doppler effect to evaluate the movement of. The probe's relative velocity and the movement of structures, usually blood, towards or away from it. The determination and visualization of the velocity and trajectory of a blood flow jet passing through a cardiac valve can be achieved through the computation of the frequency shift of a designated volume of the sample. Vascular and cardiac sonography is an important tool in cardiovascular studies, particularly for evaluating reverse blood flow in the hepatic vasculature in situations of portal hypertension [6,7]. Spectral Doppler is utilized for the visual representation of Doppler information, whereas color Doppler (also known as directional Doppler) or power Doppler (sometimes referred to as non-directional Doppler) is employed to visually show the information in the form of an imagine. The Doppler shift is within the audible spectrum and is commonly exhibited through the use of stereo speakers, resulting in a distinct, if artificial, pulsating auditory experience [8]. The basic concepts of sound and ultrasound propagation and discusses the physical principles of the Doppler effect and Doppler sonography, which are essential for understanding their diagnostic uses [9] .utilizing Doppler ultrasound. The guide focuses on optimizing Doppler ultrasound images for improved blood flow detection, addressing key factors such as gain settings, velocity scale, and transducer selection. It aims to help operators enhance skills and avoid common mistakes, maximizing the modality's potential in medical imaging [10].

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EXPERIMENTAL

The Doppler equation

If the reflector incorporates a velocity component along the ultrasonic beam, the reflected ultrasonic wave's frequency deviates from the incident wave's frequency. One may represent the relationship as follows [3]. eq.(1):

$$FD = 2v(\cos y)f/c$$

In this equation, f' denotes the received ultrasonic frequency (f'), while f D denotes the sent ultrasonic frequency (f-f'). Relatively speaking, the variables c, v, and y stand for the speed of ultrasonic waves, the speed of the reflector, and the angle of attack accordingly. Denoted as y, the angle of attack is defined as the path of the ultrasonic beam created between the directions of movement of the reflector. The often reported values for f, v, and c are 3 MHz, 1 ms^{-1}, and 1500 m s^{-1}. When y = 0, the related Doppler shift frequency, fD, is 4 kHz.

1-The choice of the ultrasonic frequency

Ultrasound depends on the signal-to-noise ratio to detect blood backscattered by it. Striking a compromise between the blood's backscattering efficiency and the intended depth of penetration helps one choose the most appropriate ultrasonic frequency. Usually spanning about 3 MHz with a penetration depth of 100 mm, the frequency range increases to 10 MHz at a depth of 20 mm. Furthermore, the Doppler frequency shift range and issues of aliasing influence the frequency choice. The Doppler shift signals can be enhanced by blood-borne contrast agents such as microbubbles, increasing the echogenicity of blood in the systemic circulation [5].

2- Doppler applications utilizing ultrasonic beams

The shape of the ultrasonic beam is determined by the transducer's geometry, the focusing arrangements, and the ultrasound's wavelength. The design concerns for pulse-echo imaging and Doppler applications exhibit three major Distinctions [2].

3- Pulsed Doppler systems

Pulse-echo range measurement considers the distances between the targets and the ultrasonic probe; therefore, it guides the choice of Doppler signals from moving objects in pulsed Doppler systems. Only when the sampling frequency equals or exceeds twice the maximum signal frequency does the resulting waveform become unambiguous, consisting of discrete values at the pulse repetition rate. We refer to this as the Nyquist criteria. If the user is not satisfied, aliasing may occur, which can generate diagnostic signals for the interpretation of the Doppler signal [6].The clock regulates the rate of pulse repetition, initiating a new pulse every 200 s. The first circuit, which has a sample length, generates a pulse that enables the oscillator to briefly produce output, thereby activating the probe's transmitting transducer. The radiofrequency amplifier magnifies the echoes the transducer picks up. The oscillator's signal next undergoes directional detection. The audio frequency amplifier filters the output from the sample-and-hold circuit before transmitting it to the frequency spectrum analyzer and the headphones [8].

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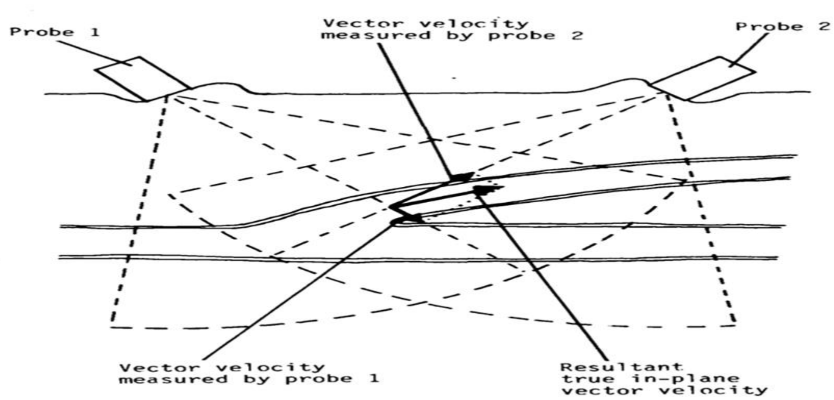
4- Presentation and analysis of Doppler signals

Diagnostic radiologists face challenges when dealing with complicated and fleeting Doppler signals, which are obtained from moving structures and flowing blood. Although certain individuals possess the capacity to extract valuable information, the trained ear is inherently subjective and lacks the ability to identify long-term trends. The Doppler signals encompass a range of frequencies and amplitudes that exhibit continuous variation as a result of the target's mobility within the ultrasonic beam. FFT analysis is employed for the purpose of graphically representing these signals and extracting quantitative data. Autoregressive modeling is a promising approach to mitigate the issue of statistical fluctuations in Fast Fourier Transform (FFT) analysis[4].

5-The display of Doppler colour flow Images

Though it does not show fixed objects, Doppler flow imaging provides a two-dimensional view of flow zones. Although they usually lack flow information, pulse-echo ultrasounds and real-time imaging devices sometimes show grayscale structures. The integration of flow imaging and real-time scanning produces a Doppler color flow map that allows for the simultaneous visualization of structure and blood flow. presented the first proof of combining two-dimensional Doppler information with pulse-echo pictures. However, Kasai first recognized the value of real-time Doppler flow imaging in 1985. The Doppler autocorrelation flow detector was designed [3].



[Fig.1]: The true in-plane vector velocity can only be successfully implemented when there are two suitable acoustic windows from different image plane positions [3].

divide Doppler signals into two distinct channels, thereby creating a temporal displacement that corresponds to the duration between consecutive ultrasonic pulses.

8- Clinical applications Cardiology

There are no established biological risks associated with Doppler ultrasound, and the US Food and Drug Administration's strategy for regulating its usage is a subject of debate. The primary causes of harm are the monetary expense of the test and the potential for incorrect

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diagnosis. Nevertheless, there is highly unlikely to be any biological hazard whatsoever. determined that the most effective methods to assure caution in the utilization of ultrasound are through adept allocation of resources, competent personnel, and properly maintained equipment, in the absence of any identified biological hazards[7].

9- Doppler ultrasound safety.

Comprehensive investigations into the biological impacts of ultrasonography have not shown any indications of danger associated with the exposure conditions employed in modern diagnostic methods has presented a compelling argument opposing the prevailing inclination towards bureaucratic regulation in relation to the utilization of Doppler ultrasound. The US Food and Drug Administration maintains that the "output" of ultrasonic instruments should not surpass that of the machines that were commonly used in clinical settings prior to the implementation of the current legislation in 1976. The contentious nature of this approach to controlling a technology that lacks any proven biological threat is evident. While it is important to avoid unnecessary exposure to ultrasonography, the responsibility of determining whether the potential benefits of the test outweigh the potential drawbacks should ideally lie with the doctor, preferably with the active involvement of the patient. Within this particular framework, the primary factors that cause harm are the monetary expense associated with the test and the potential for incorrect diagnosis; it is highly unlikely that there is any biological risk involved. Undoubtedly, there is a suggestion that ultrasound could potentially yield a minor yet measurable biological drawback. This would serve to provide a broader understanding for individuals who may lack the sensitivity to acknowledge the existence of further unidentified consequences. conducted a comprehensive investigation into the subject matter, ultimately determining that the optimal approach to ensuring prudence in the utilization of ultrasound involves the application of skill and sound judgment in resource allocation, the engagement of suitably qualified, trained, and competent personnel, and the provision of an appropriate balance of suitable and adequately maintained equipment[4,8].

10- Comparative Analysis of Sonar Images with Doppler Imaging.

The diagnosis of the patient is Uterine artery pseudo aneurysm (UAP).

In the grayscale ultrasound image, a cystic structure of 12 mm in diameter is shown within the right uterine wall. The cystic structure is precisely illustrated in order to ascertain its precise location and dimensions. There is no observable damage or insufficiency in the expansion of the arteries. Color Doppler Ultrasound Image: - Displays regular blood circulation within the dilated arteries, exhibiting diverse hues and a "yin-yang" visual patter There are no indications of damage or insufficiency in the expansion of the arteries[5]. (Figure 2).

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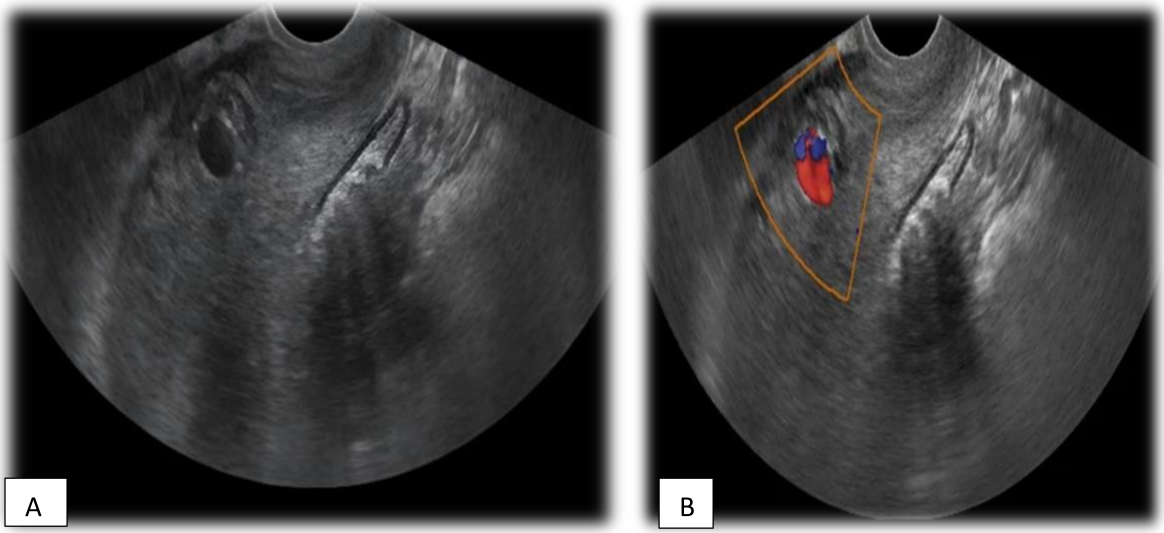

Fig. (2): (A) in the current study Gary Doppler (B) in the current study Color Doppler

Diagnosis: Left common carotid artery dilation.

Grayscale Ultrasound Image: - Shows the expansion of blood vessels in the left primary carotid artery. The shape and dimensions are illustrated to assess the magnitude and seriousness. There is an absence of observable damage or insufficiency in the arterial wall. The Color Doppler Ultrasound Image illustrates the presence of normal blood flow within the arterial dilatation, which is classified as "laminar." There are no indications of damage or insufficiency in the expansion of the arteries [2]. (Figure 3)

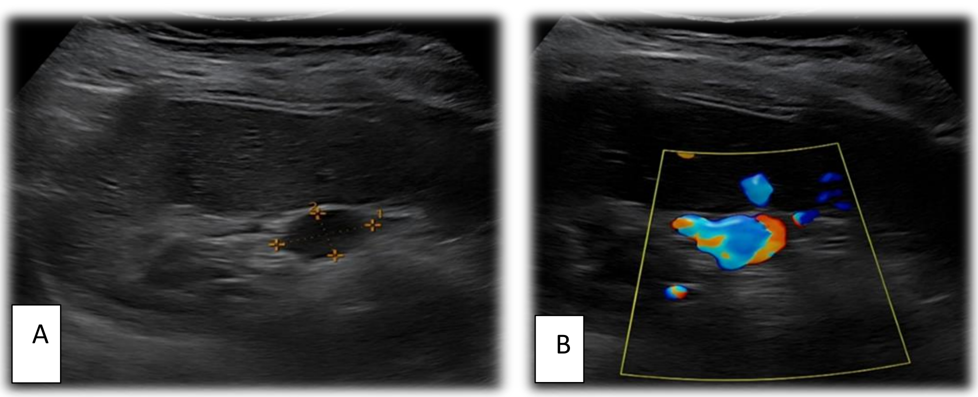

Fig.(3): (A) in the current study Gary Doppler (B) in the current study Color Doppler

Diagnosis: The presence of an abnormal blood flow pattern in the lower limbs, accompanied by modest engorgement in the hepatic veins, indicates a potential impairment in the functioning of the right ventricle. The grayscale ultrasound image illustrates atypical irregularities in blood

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circulation inside the lower extremities. The hepatic veins exhibit a little engorgement. There is no indication of thrombosis An irregular blood flow pattern is observed in the color Doppler image, characterized by changed Signifies atypical blood circulation in the hepatic veins [6]. (Figure 4)

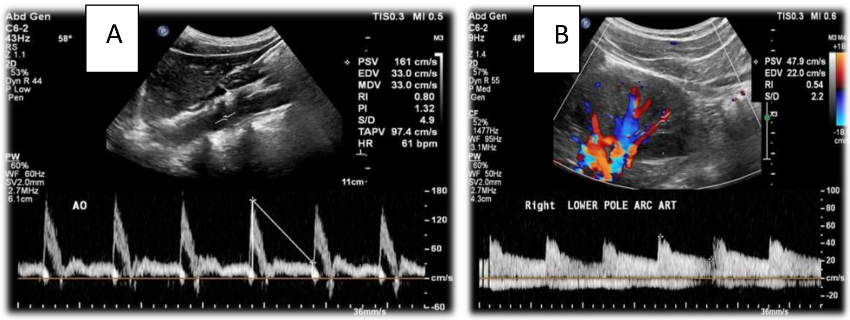
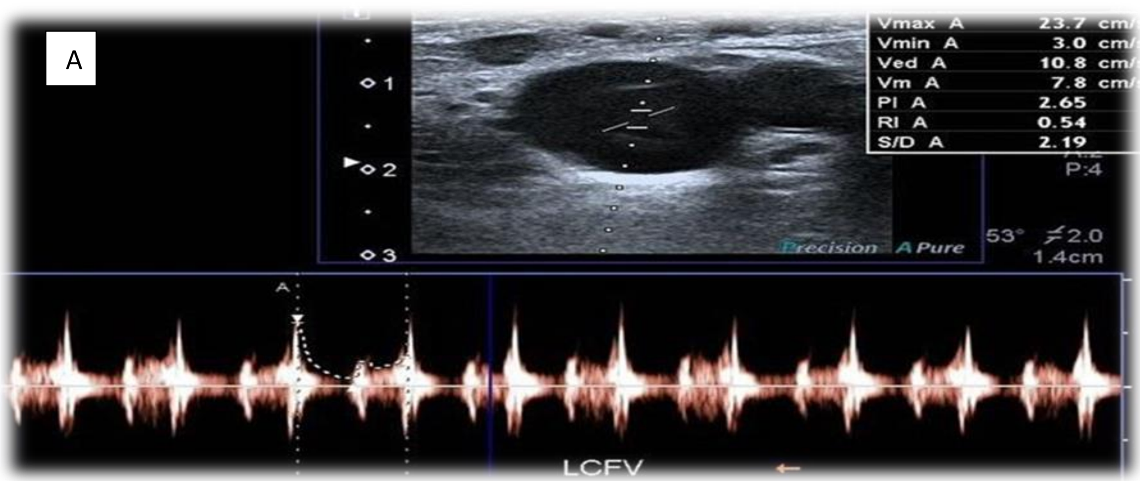


Fig. (4) : (A) in the current study Gary Doppler (B) in the current study Color Doppler

The diagnostic process involves evaluating renal function and identifying the presence of renal artery stenosis. The grayscale ultrasound image provides a visual representation of the kidneys, offering an approximation of their dimensions and morphology. This study assesses the dimensions and morphology of the renal arteries. There are no indications of atypical expansion or irregularities in the blood vessels. The color Doppler image demonstrates the presence of regular blood circulation within the renal arteries. Categorizes the circulation of blood and calculates the amount of blood in the renal arteries [5]. (Figure 5)



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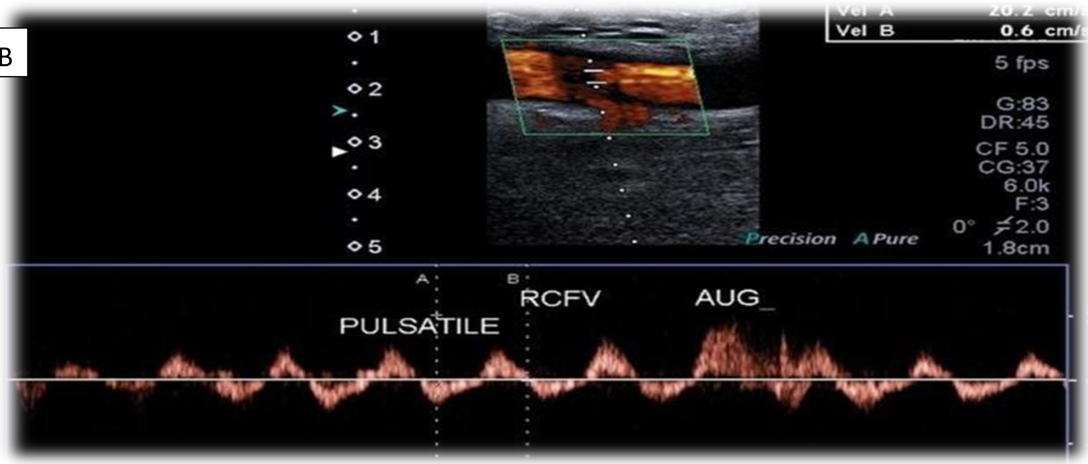

Fig. (5): (A) in the current study Gary Doppler (B) in the current study Color Doppler

Table 3.1 Comparative Analysis of Sonar Images with Doppler Imaging for

Aspect	Doppler Gray	Doppler
Principle	Utilizes Doppler effect for health monitoring	Utilizes Doppler effect for various applications
Color	Gray	Varies (depending on model)
Applications	Health monitoring (heart rate, blood pressure)	Medical imaging (ultrasound, radar), astronomy, etc.
Accuracy	High	High
Efficiency	Suitable for personal health tracking	Versatile, applicable in various fields
Disease Diagnosis	Limited to health tracking	Used in medical imaging for diagnosing conditions
Portability	Typically wearable, portable	Depends on specific application (e.g., medical devices vs. radar systems)
Cost	Generally affordable for personal use	Cost varies based on application and complexity
User Interface	Designed for ease of personal use	May require specialized training in certain application

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RESULTS AND DISCUSSION

The findings of the study revealed notable differences in image quality and diagnostic capacities between Gray Doppler and Color Doppler. In comparison to conventional grayscale imaging, Color Doppler ultrasound demonstrated enhanced precision and detail in the visualization of blood flow dynamics, hence facilitating more precise diagnosis of vascular problems. In the field of medical imaging, both modalities provided precise representations of anatomical features and the patterns of blood flow within cysts and arterial dilations. Color Doppler ultrasound improved the clarity and detail of determining the distribution of blood flow within blood vessels, hence boosting the accuracy of diagnosis[10].

Understanding the physics of Doppler ultrasound is essential for accurately interpreting medical images and findings. Sound waves reflected from moving objects change frequency, enabling Doppler ultrasonography. This knowledge helps diagnose vascular diseases by analyzing blood flow patterns. Doppler ultrasound can diagnose cardiovascular illnesses, congenital heart abnormalities, and therapy efficacy. Understanding physical principles improves image quality and diagnostic accuracy, resulting in improved patient care and treatment outcomes. Technological advances in Doppler ultrasonography improve imaging and diagnosis. Future research may improve Doppler ultrasound procedures, explore novel therapeutic applications, undertake cost-effectiveness studies, and improve healthcare professional education and training [10].

CONCLUSIONS

Investigate novel applications of Doppler Ultrasound technology throughout diverse medical domains, including the diagnosis of cardiovascular ailments, facilitation of congenital heart defect procedures, and assessment of therapy impacts on blood circulation.

Conflict of interests.

Non conflict of interest

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الخلاصة

مقدمة

أظهرت البيانات أن الدوبلر الرمادي الملون يتمتعان بجودة صورة وقدرات تشخيصية مختلفة تمامًا. يُظهر التصوير بالموجات فوق الصوتية دوبلر الملون ديناميكيات تدفق الدم بشكل أكثر دقة من التصوير بالتدرج الرمادي، مما يتيح تشخيصًا أكثر دقة للأوعية الدموية. وصفت كلتا طريقتي التصوير الطبي الخصائص التشريحية بدقة، وأنماط تدفق الدم في الكيس، وتوسع الشرايين.

طرق العمل

يتم إجراء فحص دوبلر بنفس طريقة الأمواج فوق الصوتية العادية، حيث بعد دهن الجل على منطقة الفحص يوضع المحوّل على المنطقة، ويقوم الفاحص المختص بالأمواج فوق الصوتية أو الطبيب بتحريكه حتى يحصل على إشارة جيدة .يجب المحاولة والحدّ من الحركة قدر الإمكان، كذلك من الممكن أن تسمعوا الأصوات التي تمثل تدفق الدم في الأوعية الدموية.

النتائج

كشفت نتائج الدراسة عن وجود تباينات كبيرة في قدرات الدوبلر الرمادي الملون على تشخيص المشكلات وتقديم صور عالية الجودة. بالمقارنة مع التصوير التقليدي بالتدرج الرمادي، أظهر التصوير بالموجات فوق الصوتية دوبلر الملون دقة وتفاصيل أكبر في تصوير ديناميكيات تدفق الدم، مما يسمح باكتشاف أكثر دقة لتشوهات الأوعية الدموية. في مجال التصوير الطبي، أنتجت كلتا الطريقتين عمليات إعادة بناء تفصيلية للخصائص التشريحية بالإضافة إلى أنماط تدفق الدم داخل الأكياس وتوسيع الشرايين.

الاستنتاجات

باستخدام التقنية الفيزيائية لتعزيز دقة وفهم الصور الطبية تم تحقق باستخدام الموجات فوق الصوتية دوبلر في الإعدادات السريرية المتقدمة مثل تشخيص اضطرابات القلب والأوعية الدموية ووجدت ذات دقة عالية في التشخيص.

كلمات مفتاحية: الموجات فوق الصوتية ، دوبلر الرمادي الملون ، الاوعية الدموية، التصوير الطبي .

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