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MEDTECH REVIEW: THE 2021 TRANSCRANIAL DOPPLER ULTRASOUND

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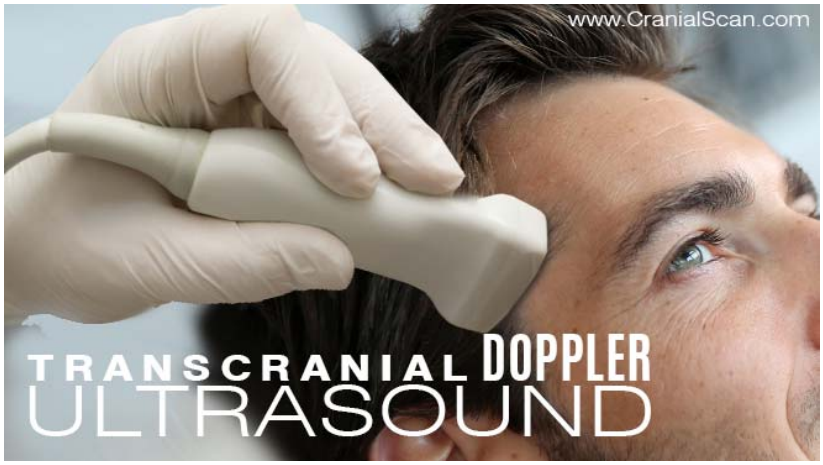
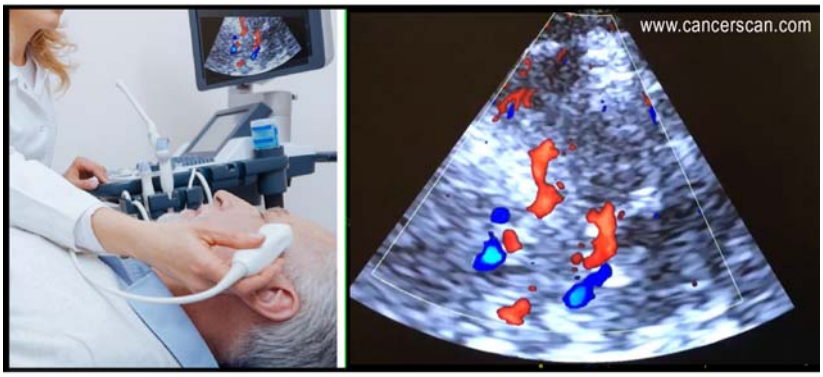


The use of ultrasound imaging has vastly expanded in utility and performance since its earliest medical applications in the mid seventies for its ability to monitor live-action imaging of developing fetuses. Its intelligent use of sound waves and echo reflection became widely accepted for being the safe, inexpensive, repeatable and non-invasive alternative in medical imaging. It fast became the standard procedure for pediatric use and continues to earn the confidence of radiologists and imaging specialists in patient care - from emergency critical care to cancer screening.

THE SCIENCE OF BLOOD FLOW, CEREBRAL AUTOREGULATION & HEMODYNAMICS with TRANSCRANIAL DOPPLER TECHNOLOGY

Hemodynamics is defined as the study of blood flow in relation to the status of the circulatory system and homeostatic mechanisms of autoregulation. Through the monitoring of blood flow, diagnostic analysis can provide many answers to the health and physiological status of the target area scanned as well as cell-level metabolism, the regulation of the pH, osmotic pressure and temperature of the whole body, and the protection from microbial and mechanical harm.[1] Assessing injuries, inflammation or mutative growths (like cancer tumors), assessment of blood flow provides diagnostic answers about the severity of tissue disorders or tumor malignancy.

The expansion of ultrasound research and development broke new ground in 1982 when Dr. Rune Aaslid (Norwegian Neurosurgical researcher) first introduced Cerebral Hemodynamics with the implementation of Transcranial Doppler science to offer noninvasive transcranial recorded imaging of flow velocity in basal cerebral arteries. His report detailed that placing an accurately configured doppler ultrasound transducer in the temporal area (just above the zygomatic arch) offers quantitative data of the rate of blood activity in the middle, proximal anterior and posterior cerebral arteries.[1.2] This scan is critical for detecting vasospasms and for



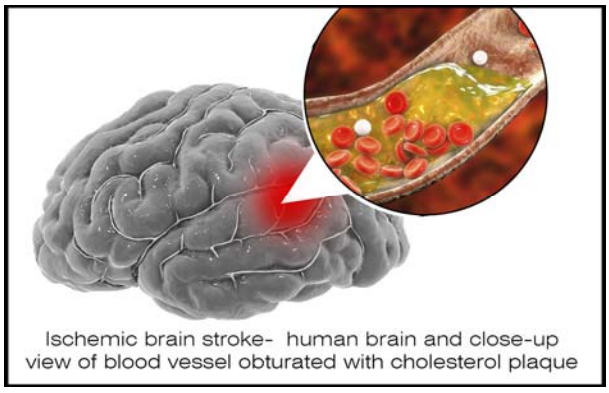
Adult patient case suspect of potential narrowing of the middle cerebral artery however a repositioned Scan(R) w/ normal doppler flow approximating 60cm/s implies no disease in the artery except for tortuosity

reviewing circulation in the brain for potential disease of the carotid and vertebral arteries. [1.5]

In 1989, Dr. Aaslid published the first review on Cerebral Autoregulation- a biological and metabolic maintenance function (in mammals) dedicated to stabilizing cerebral blood flow. TCD scans and detects the slightest inconsistency in perfusion-- the volumetric measure at which blood is delivered to tissue, or volume of blood per unit time per unit tissue mass. Alongside the study of blood pressure, Cerebral Autoregulation is vital to maintaining life as it supports proper delivery of adequate oxygen (in the blood) and nutrients to the brain and the removal of CO2 & other waste products.[2] As Dr Aaslid used the TCD by scanning with the transtemporal approach, others explored the intracranial arteries through the orbital (eye socket) window. By the early 90's, the next generation of development teams (Spencer, Seidel, Dobson & Moehring) improved on the Doppler innovation to detect microemboli and hemodynamic physiology. Today, TCD is widely accepted and utilized for an expanding set of clinical and research applications including ischemic stroke, sickle cell disease, subarachnoid hemorrhage and vasospasm.

According to cancer diagnostic imaging expert Dr. Robert Bard, the introduction of Doppler technology aligned with the ultrasound's base design concept of providing instantaneous, real time readings. "Let's take the case of breast cancer screening, the technician simply puts the probe on the breast, find the area, pinpoint it, press a button and seconds later you have the map showing the types of vessels, the location of the vessels. You have functions that give you a vessel density measurement which shows how aggressive this is. Instead of genetic markers (which are very popular), visually showing how aggressive a tumor can be in a matter of seconds to show cancer vessel aggression is a game-changer for any early detection or monitoring facility. Tumor aggression by blood flow evaluation is used worldwide in nuclear medicine, CT scans and MRI technology, however, one of the simplest and most cost-effective alternatives is the non - invasive 3D Doppler breast procedure."

INTERCRANIAL SCANNING WITH DOPPLER ULTRASOUND


Ischemic brain stroke- human brain and close-up view of blood vessel obturated with cholesterol plaque

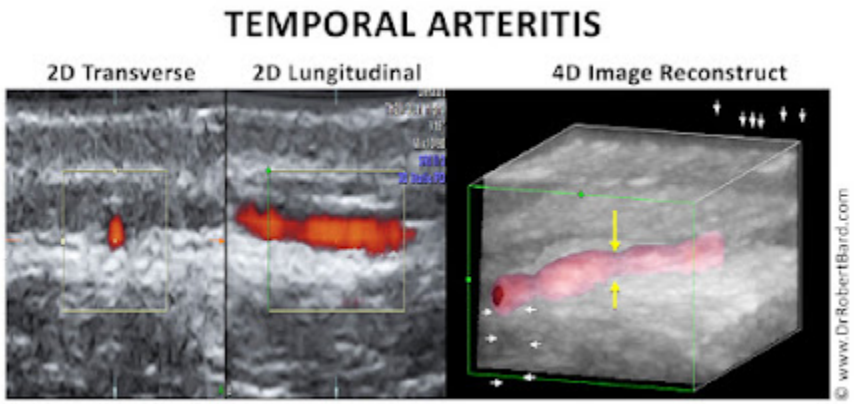
In 1982, continued advancement led to the Transcranial Doppler (TCD) ultrasonography for outpatient and inpatient settings. By integrating the ability to study BLOOD FLOW to a low-frequency transducer, placing the probe on the temporal area can measure the cerebral arteries to detect and quantify cerebrovascular activities, diseases and brain injuries. Other applications include the diagnoses of vasospasm (VSP) after an aneurysm rupture or hemorrhage or hemodynamic changes after ischemic or cryptogenic stroke. It enables the study of cranial pressure fluctuations.

TCD also offers significant clinical benefits in the monitoring of sickle-cell disease by scanning brain stem death and elevated raised intracranial pressure (ICP). Added features allow for surgical and post-op monitoring of vasomotor functions as well as detecting critical disorders like a microembolism.

VERIFYING SIGNS OF COVID-19 STROKE THROUGH IMAGING

By: Robert L. Bard, MD and Dr. Pierre Kory, MD

Early detection and prevention of arterial and venous disease is key to minimizing the effects of arterial obstruction & hemorrhage, brain aneurysms, and strokes from venous thrombosis. The association of trauma to PTSD is now followed by advanced Doppler ultrasound and functional MRI. This abnormal physiology may also manifest as arterial dissection, collagen disease, inflammatory arthritis, dermatitis, ocular disorders, GI disturbances, limb pain, aneurysms of the brain and aorta. Devastating strokes in the Covid-19 era occur in the younger age group and the Latin population is at higher risk.

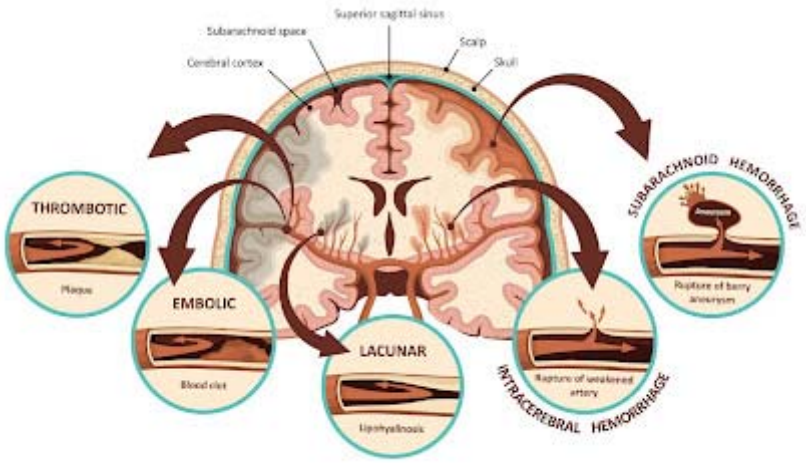


Arterial narrowing in patient with headache / visual changes

INTRODUCTION

Interest in arteritis was elevated with the study of Tayakasu's disease in the 1970s when advances in contrast arteriography diagnosed diffuse vascular involvement causing strokes and aneurysms in multiple sites. While this arterial inflammation is more common in Asians, in the US, blacks are nearly three times more likely to have a stroke at age 45 than whites. The pediatric population seems to be at higher risk for this arteritis as evidenced by their unusual rate of Covid-19 affliction affecting the vasculature and called "MULTIPLE ACUTE INFLAMMATORY SYNDROME". Birth control pills is a distinct cause of such disease in younger women while cancer, alcoholism and obesity raise the incidence at all ages. [3]

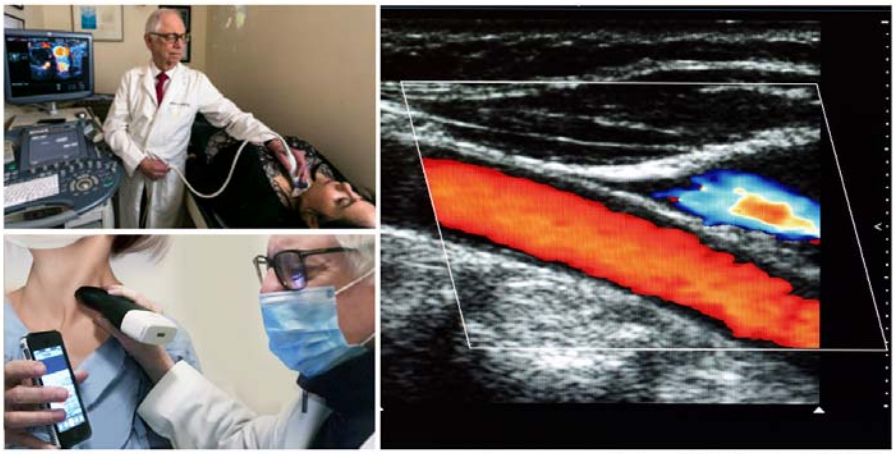
We have learned over the last century that blockages of coronary arteries to the heart and carotid arteries to the brain are precipitated by inflammation of the inner walls of the vessel, called the "intima"



ISCHEMIC vs HEMORRHAGIC STROKE

While thickening of the interior wall of vessels gradually occurs over time and is aggravated by diet, stress and hypertension (high blood pressure), the acutely disabling event is when there is an abrupt tear of the overlying plaque which ruptures debris which then forms a blood clot which blocks blood flow or the clot travels deeper into the brain and blocks blood flow. Similarly, abnormal heart rhythms such as "atrial fibrillation", causes the pooling of blood in the heart which predisposes to clot formation and the clots can then travel into the brain causing a stroke. In Covid-19, the virus causing severe inflammation in the blood which then promotes clot formation which can travel through the vascular system and affect almost every organ system in the human body, with the brain and lungs being the most affected.. An article in September NEUROLOGY reported by Medscape documented the incidence of large artery stroke as the presenting symptom of COVId-19 was highest in men under the age of 50 years. [4]

CAROTID SONOGRAM: While cerebrovascular disease is often diagnosed ex post facto after a catastrophic episode with MRI and CT, the non invasive Doppler analysis of the vascularity is generally checked with ultrasound for plaque and obstruction. A useful measure of the risk of coronary and cerebrovascular disorder is the carotid intimal thickness (CIMT). Standard depth of the inner wall thickness is a measure best obtained by high resolution sonograms since a reading over 0.9mm indicates increased risk. The newer sonogram units have depth resolution of 0.02mm making this a preferred non invasive option.



Dr. Robert Bard conducts cerebrovascular scans of the CAROTID DUPLEX with a doppler ultrasound to detect potential ischemic strokes, aneuysms or intracranial stenosis.

CAROTID DOPPLER: Flow abnormalities of turbulence and absence are commonly evaluated with this modality. Plaque forms more readily in aberrant flow patterns and high velocity regions accompanying narrowing.

EYE SONOGRAPHY: Sonofluoroscopy of the orbital soft tissues and eyes is performed in multiple scan planes with varying transducer configurations and frequencies. Power and color Doppler use angle 0 and PRF at 0.9 at optic nerve head. 3D imaging of optic nerve and carotid, central retinal arteries and superficial posterior ciliary arteries performed in erect position before and after verbal communication. Retinal arterial flow is measured. Optic nerve head bulging is checked as increased intracranial pressure may be demonstrable.

TRANSORBITAL DOPPLER: R/L ciliary arteries have normal Doppler flows of 10cm/s which is symmetric.

CONTRAST ENHANCED ULTRASOUND: Widely used European nonionic contrast injection allows imaging capillary size vessels and perfusion characteristics

TRANSCRANIAL DOPPLER: This measures the flow in the anterior, middle and posterior cerebral arteries as well as Circle of Willis.

3D/4D VESSEL DENSITY HISTOGRAM: Multiple image restoration and reconstruction shows retinal vessel density of 25% at the optic nerve head and adjacent region with quantitative accuracy.

ENDOARTERIAL 3D DOPPLER: Microcatheters inserted into the arterial or venous system provide measurement of wall thickness and presence of inflammatory vessels inside the intima.

RETINAL OCT: Subtraction techniques done with OCT optical coherence tomography may show changes in the caliber of the retinal vessels with verbal ideation.

SOFT TISSUE OCT: The depth of penetration may be extended to 2-3mm allowing for analysis of vascular changes in erythematous or erythropoor dermal areas. Thrombosis may be observed.

REFLECTANCE CONFOCAL MICROSCOPY: This microscopic analysis of the cells also quantifies microvascular pathology and is a potential modality for studying vasculitis.

SMALL COIL MRI: High resolution systems used for animal study and superficial organs can image the intra-arterial anatomy including dynamic contrast imaging on standard 1.5T and 3T units.

7 TESLA MRI: High field systems analyse signal abnormalites rapidly with high resolutions.

HYBRID IMAGING: Hybrid imaging refers to combining diagnostic modalities to assess disease and monitor therapy.

REF

1) Hemodynamics: https://en.wikipedia.org/wiki/Hemodynamics
1.2) Journal of neurosurgery
ttps://scholar.google.com/citations?view_op=view_citation&hl=en&user=fEwhsrcAAAAJ&alert_preview_top_rm=2&citation_for_view=fEwhsrcAAAAJ:QIV2ME_5wuYC
1.5) Noninvasive transcranial Doppler ultrasound recording of flow velocity in basal cerebral arteries
R Aaslid, T M Markwalder, H Nornes
https://pubmed.ncbi.nlm.nih.gov/7143059/
1.7) About Merrill P. Spencer, MD: https://esnch.org/in-memoriam/
2) https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5224659/
3). Hassani SN, Bard RL: Ultrasonic Diagnosis of Abdominal Aortic Aneurysms. J. Natl. Med. Assoc. 66:298-299, July 1974
4). Lande A, Bard RL: Arteriography of Pedunculated Splenic Cysts. Angiology 25:617-621, October 1974
5). Lande A, Bard RL, Rossi P: Takayasu's Arteritis: A World Entity. N.Y. State J. Med. 76:1477-1482, Sep 1976
6). Helbick Eur Radiol 30:5536-5538, 2020
7). Mao l JAMA Neurol 2020 77:683-690