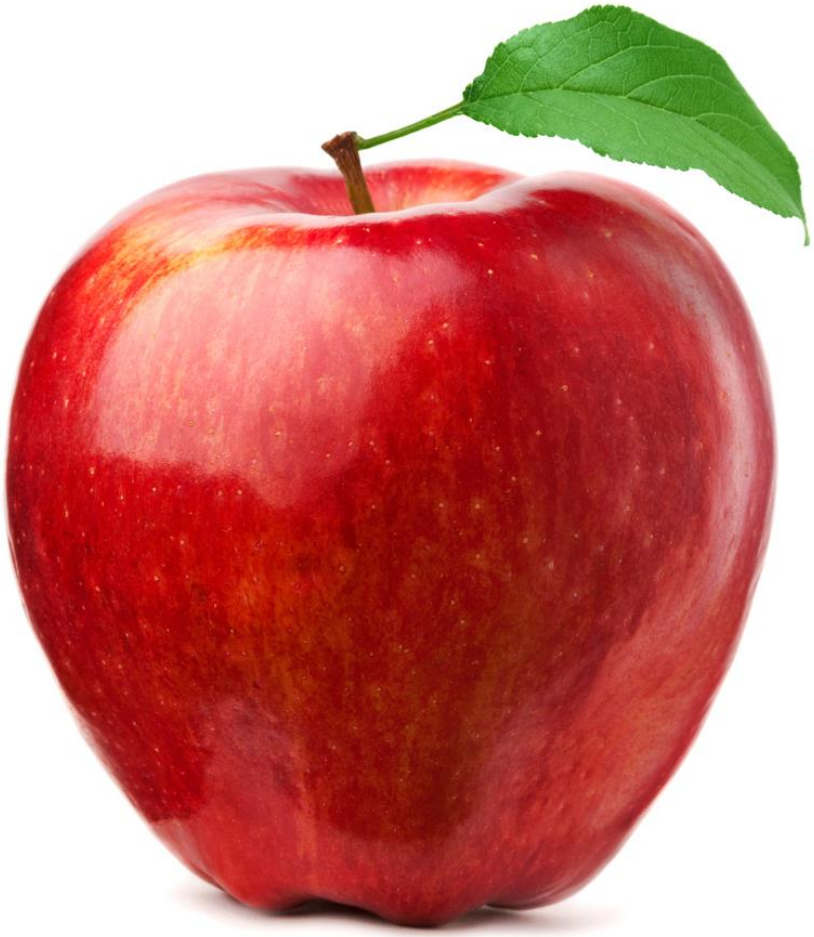
Physiologic Testing vs. Duplex Imaging for Peripheral Arterial Disease

"Duplex Imaging is All I Really Need"

David L. Dawson, MD, RPVI, RVT

Point



Counterpoint

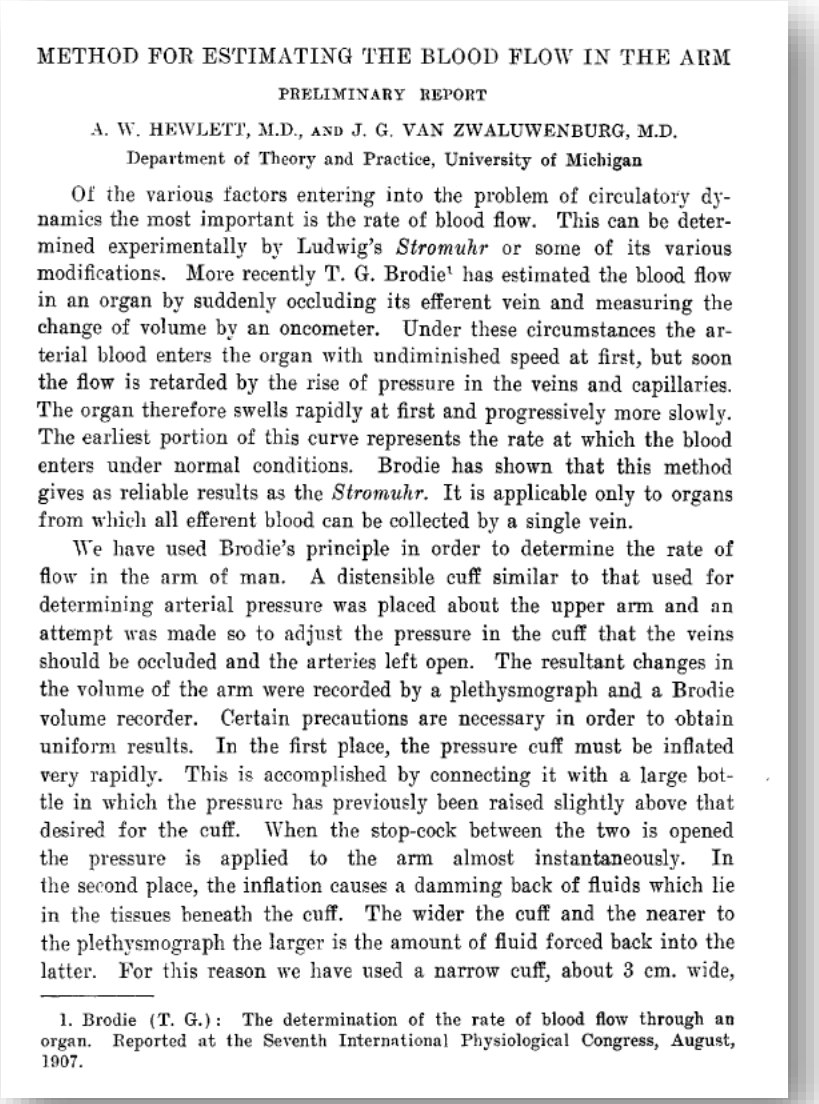

MIS EN BOUTEILLE AU CHÂTEAU
CHATEAU LAFITE ROTHSCHILD
PAUILLAC

Duplex Scanning vs. Physiologic Testing

- History
- Value of velocity criteria
- Value of waveform analysis
- Value of imaging (B-mode and color Doppler)
- Utility in clinical practice
  - Decision to treat
  - Decision how to treat
  - Evaluation of results of treatment
  - Surveillance – natural history and long-term outcomes of treatment

Plethysmography

- 1909 publication in Archives of Internal Medicine of Chicago
  - AW Hewlett and JG Van Zwaluwenburg
  - University of Michigan
- Described changes in limb blood volume, measured with pneumatic cuff
- Attached to plethysmograph with tubing



METHOD FOR ESTIMATING THE BLOOD FLOW IN THE ARM

PRELIMINARY REPORT

A. W. HEWLETT, M.D., AND J. G. VAN ZWALUWENBURG, M.D.

Department of Theory and Practice, University of Michigan

Of the various factors entering into the problem of circulatory dynamics the most important is the rate of blood flow. This can be determined experimentally by Ludwig's *Stromuhr* or some of its various modifications. More recently T. G. Brodie[1] has estimated the blood flow in an organ by suddenly occluding its efferent vein and measuring the change of volume by an oncometer. Under these circumstances the arterial blood enters the organ with undiminished speed at first, but soon the flow is retarded by the rise of pressure in the veins and capillaries. The organ therefore swells rapidly at first and progressively more slowly. The earliest portion of this curve represents the rate at which the blood enters under normal conditions. Brodie has shown that this method gives as reliable results as the *Stromuhr*. It is applicable only to organs from which all efferent blood can be collected by a single vein.

We have used Brodie's principle in order to determine the rate of flow in the arm of man. A distensible cuff similar to that used for determining arterial pressure was placed about the upper arm and an attempt was made so to adjust the pressure in the cuff that the veins should be occluded and the arteries left open. The resultant changes in the volume of the arm were recorded by a plethysmograph and a Brodie volume recorder. Certain precautions are necessary in order to obtain uniform results. In the first place, the pressure cuff must be inflated very rapidly. This is accomplished by connecting it with a large bottle in which the pressure has previously been raised slightly above that desired for the cuff. When the stop-cock between the two is opened the pressure is applied to the arm almost instantaneously. In the second place, the inflation causes a damming back of fluids which lie in the tissues beneath the cuff. The wider the cuff and the nearer to the plethysmograph the larger is the amount of fluid forced back into the latter. For this reason we have used a narrow cuff, about 3 cm. wide,

1. Brodie (T. G.): The determination of the rate of blood flow through an organ. Reported at the Seventh International Physiological Congress, August, 1907.

Strain Gauge Plethysmography

J. Physiol. (1953) 121, 1–27

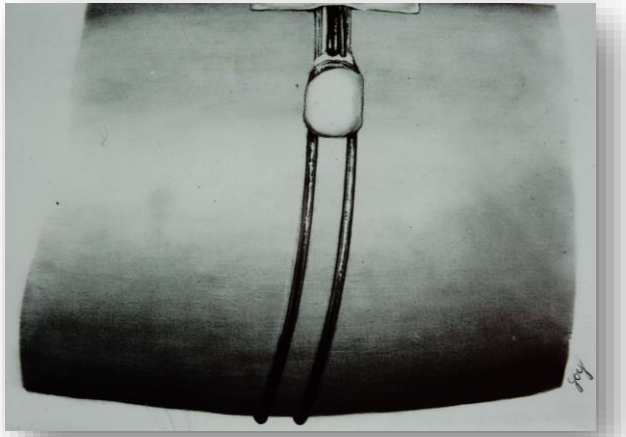
THE MEASUREMENT OF VOLUME CHANGES IN HUMAN LIMBS

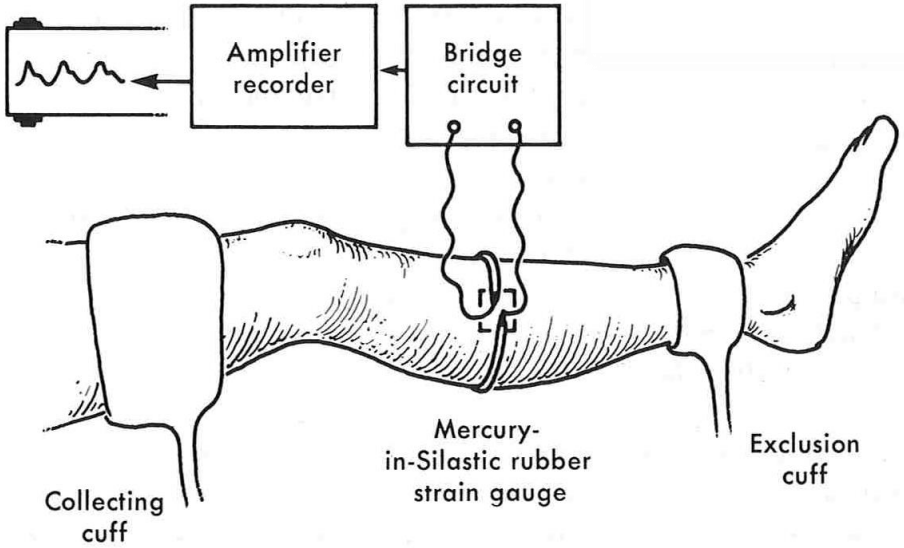
By R. J. WHITNEY

From the Medical Research Council Unit for Research on Climate and Working Efficiency, Department of Human Anatomy, University of Oxford

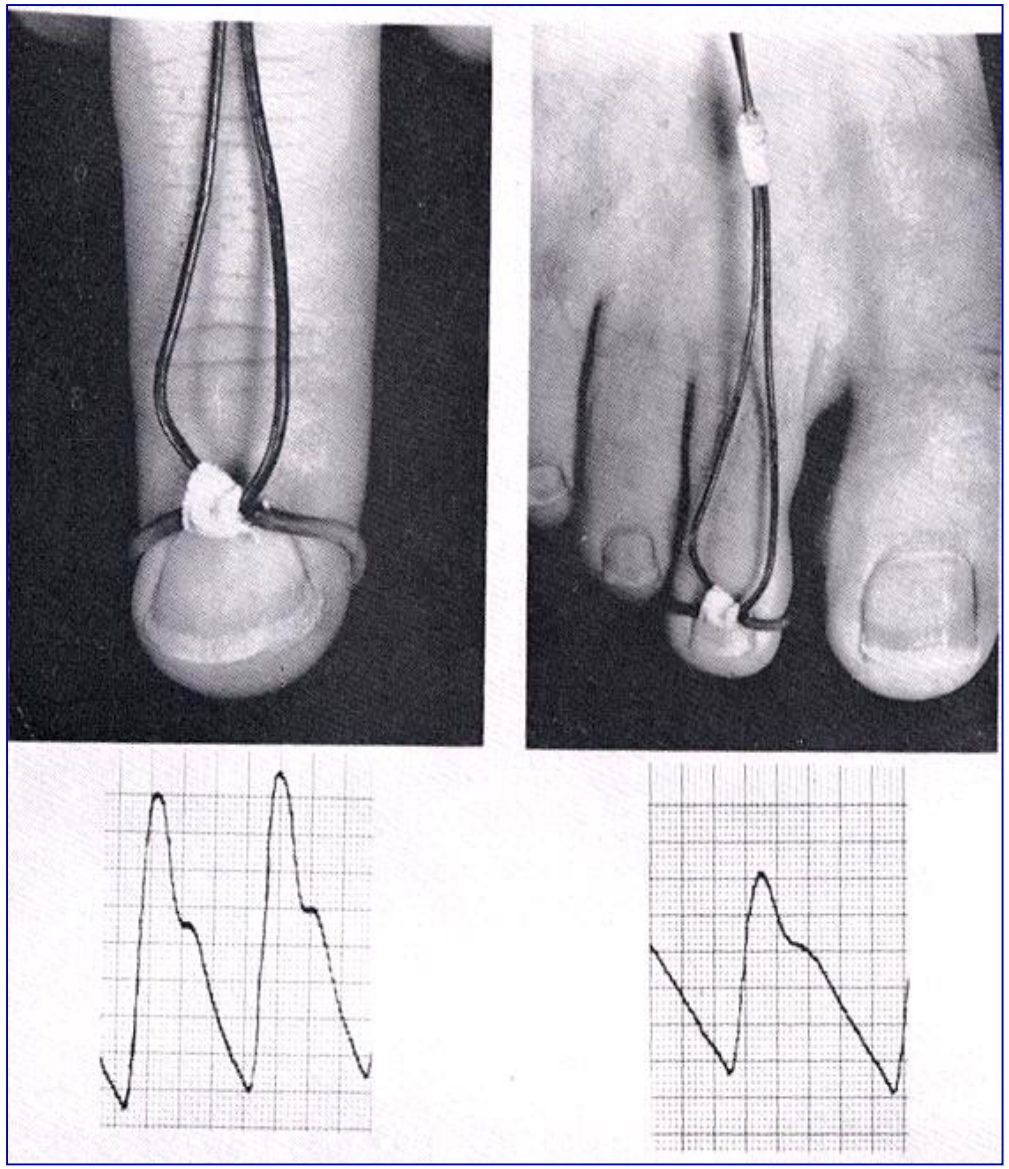
(*Received* 1 *September* 1952)

The measurement of volume changes in the limbs or in portions of the limbs of man is now recognized as a valuable technique in many physiological and clinical investigations. The various methods employed in the measurement have been recently reviewed (Potter, 1948). Volume plethysmography has proved particularly useful in investigations on vasomotor response and, combined with the venous occlusion procedure, has become the standard method for estimating peripheral blood flow in man.





Arterial Plethysmography



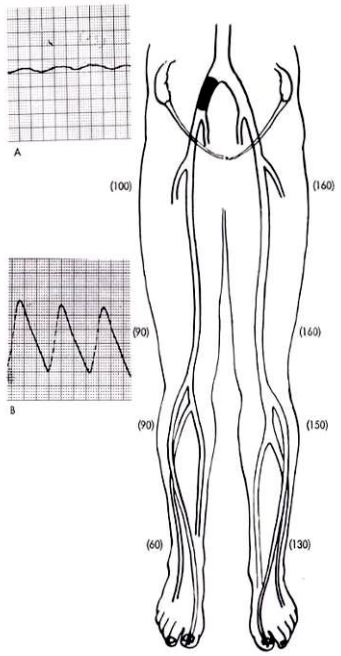
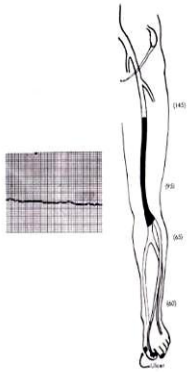


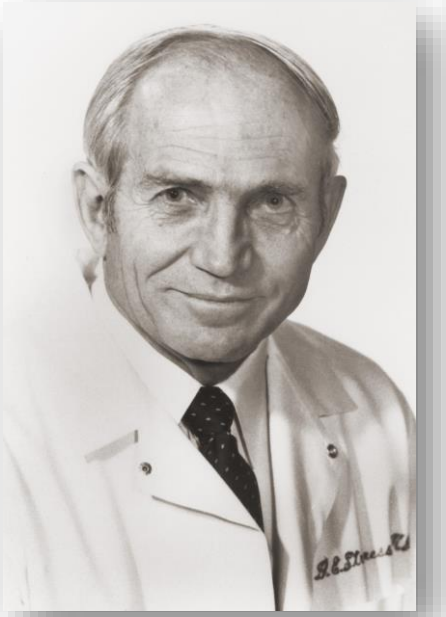
FIG. 5. Low right groin pressure establishes occlusion to be above inguinal ligament and involving iliac artery. Preoperative pulses (A) are typically low in amplitude and flattened. After a successful endarterectomy, digit pulses have a normal volume and contour (B).

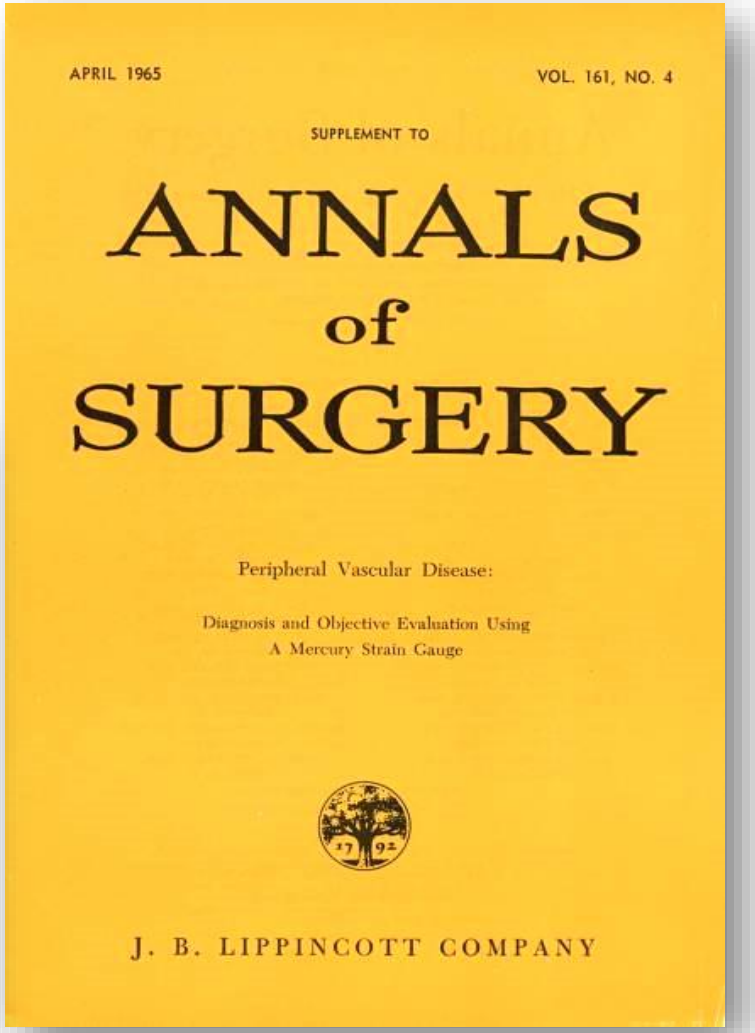
FIG. 6. Large pressure drop from upper thigh to below knee suggests extensive occlusive involvement including popliteal artery. Absence of a digit pulse following a reactive hyperemia test suggests that critical areas of collateral circulation are involved.

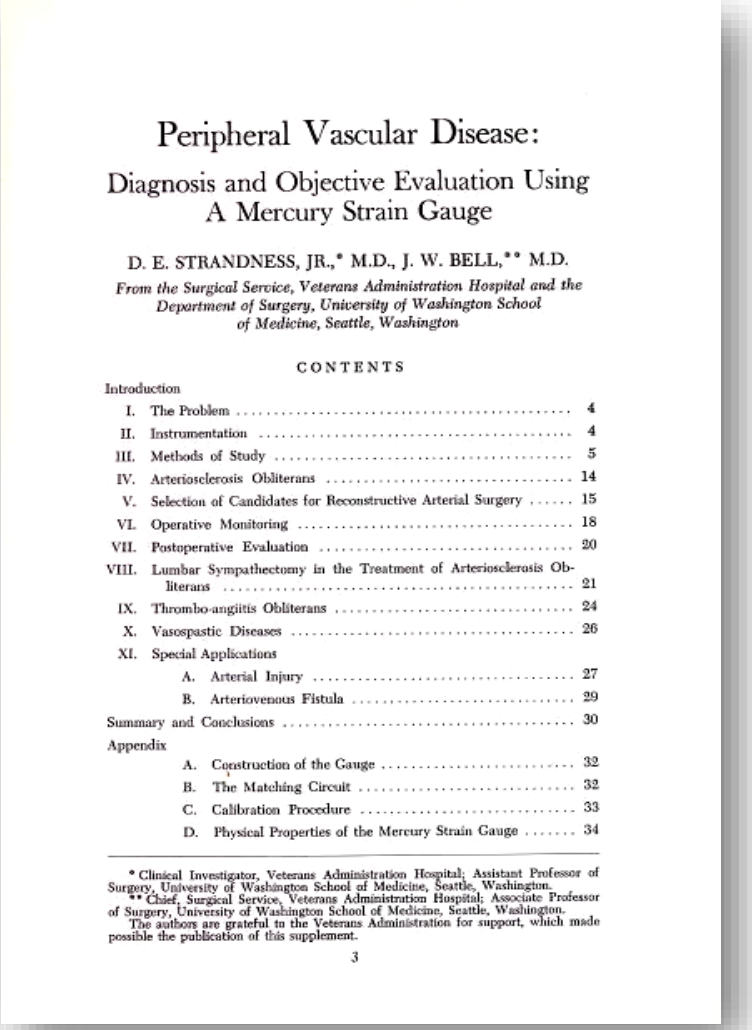


Indirect Physiologic Testing

- Strain-gauge plethysmography
- Arterial pressures and waveforms







Peripheral Vascular Disease:

Diagnosis and Objective Evaluation Using A Mercury Strain Gauge

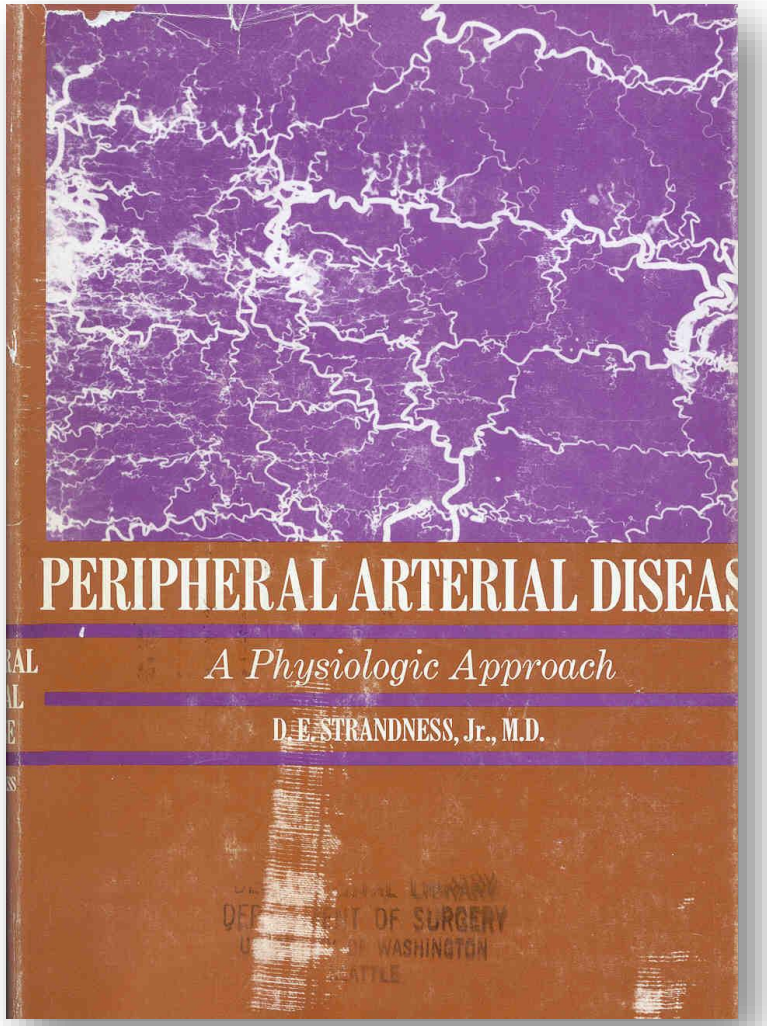
D. E. STRANDNESS, JR.,* M.D., J. W. BELL,** M.D.

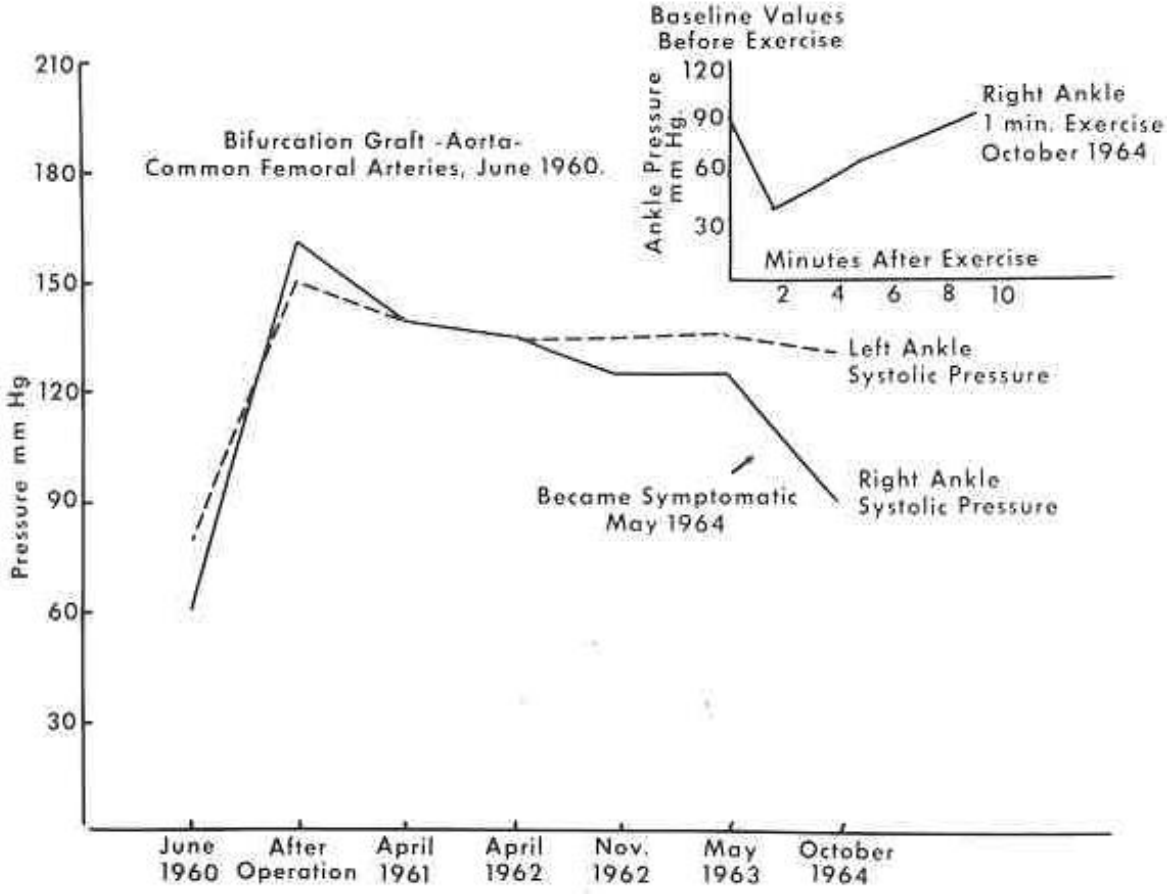
From the Surgical Service, Veterans Administration Hospital and the Department of Surgery, University of Washington School of Medicine, Seattle, Washington

CONTENTS

* Clinical Investigator, Veterans Administration Hospital; Assistant Professor of Surgery, University of Washington School of Medicine, Seattle, Washington.
** Chief, Surgical Service, Veterans Administration Hospital; Associate Professor of Surgery, University of Washington School of Medicine, Seattle, Washington.
The authors are grateful to the Veterans Administration for support, which made possible the publication of this supplement.

3





"When the distal anastomosis narrowed, the ankle pressure began to decrease and the exercise test was abnormal.
After the anastomosis was revised, the ankle pressure increased to 130 mm Hg and claudication disappeared"

Doppler Flow Detection

- 1959 – Satomura reported use of ultrasound to detect blood flow in peripheral circulation
- 1961 – Franklin, Schlegal and Rushmer described an “ultrasonic flowmeter” based on the Doppler effect for use in animals
- 1963 – Watson and Rushmer showed feasibility of detecting blood flow with ultrasound through human skin
- 1966 – Strandness described clinical applications of the Doppler flowmeter

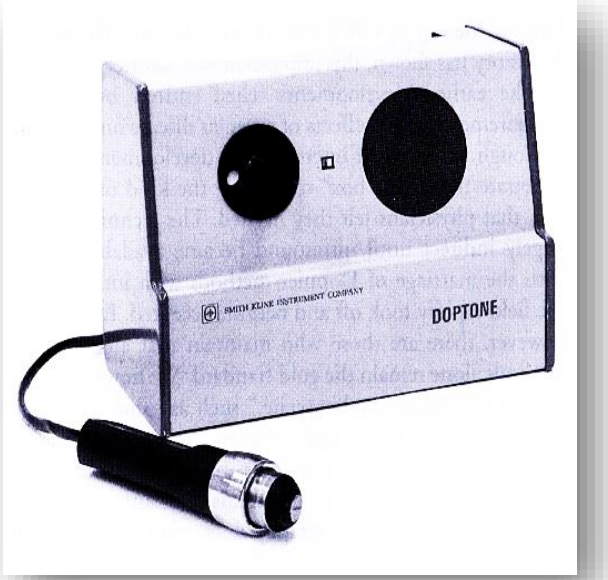
Shigeo Satomura
1919–1960

Continuous Wave Doppler

Prototype Doppler
University of Washington

ca. 1962 – Don Baker and colleagues

First Commercial Doppler



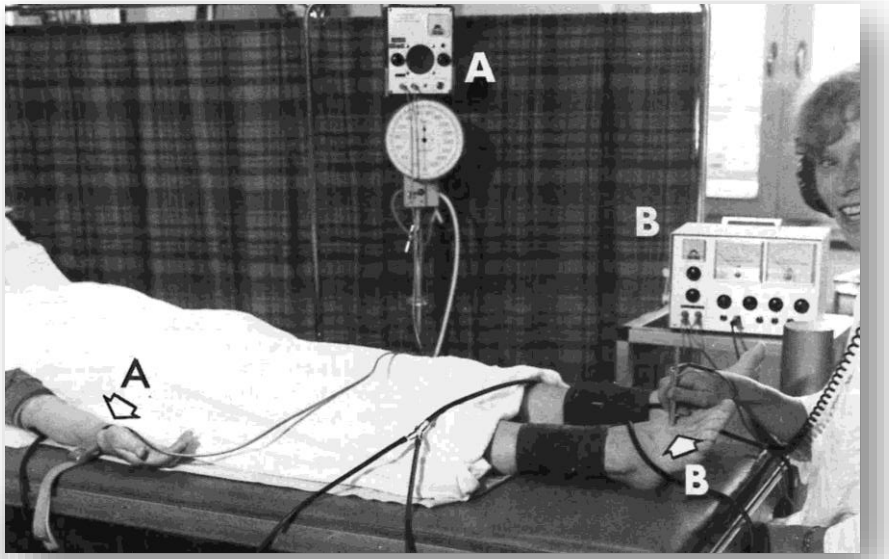
Strandness DE et al. Ultrasonic flow detection: A useful technique in the evaluation of peripheral arterial disease. *Am J Surg* 1967


HOLD
COUNTDOWN
PROCEED
ELAPSED TIME
OPERATIONS DIRECTOR

Introduction of Continuous Wave Doppler

- Continuous-wave Doppler
  - Indirect limb blood pressures
  - Analog arterial waveform
- Vascular lab tool
  - Pressure measurements
  - Qualitative assessments
- Point-of-care testing

Doppler Applications



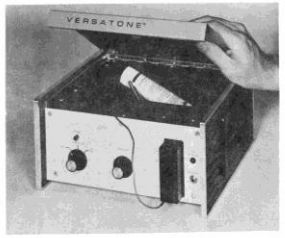
Announcing

VERSATONE™ Doppler

A Diagnostic Doppler Ultrasound Instrument

for use in Surgical Applications

The Medsonics VERSATONE™ Doppler is a portable diagnostic ultrasound instrument with built-in loudspeaker. VERSATONE features interchangeable, electrically insulated probes. All probes are factory tuned for optimal performance, and no operator adjustments are necessary. A large flat probe for air bubble detection over the right atrium during neurosurgical procedures may be interchanged with sensitive gas-sterilizable pencil probes for intraoperative use. Other probes suitable for use with the instrument will soon be available. Options available include an electrocautery cut-out that automatically eliminates interference generated by certain electrocautery machines.



- Interchangeable flat and pencil-shaped probes give flexibility often needed in diagnostic applications of Doppler ultrasound.
- All probes electrically insulated for patient safety.
- Easy to use — no retuning necessary as probes of various frequencies are interchanged.
- Operates 20 hours or more on internal rechargeable batteries, or directly from AC line current.

MEDSONICS, INC.

790 HEMMETER LANE • P.O. BOX M, MOUNTAIN VIEW, CALIFORNIA 94042 • TELEPHONE (415) 965-3333

ULTRASONIC DOPPLER

FLOW DETECTOR

MODEL 812
$400

MODEL 822
$450

TRANSCUTANEOUS BLOOD-VELOCITY DETECTORS WITH OUTPUT FOR RECORDING OF ARTERIAL AND VENOUS BLOOD VELOCITY WAVEFORMS

Impedance Plethysmography

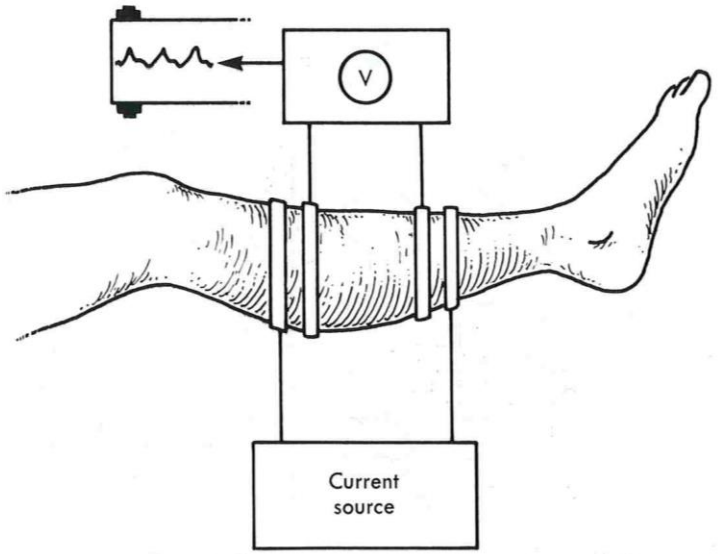


Fig. 8-6. Impedance plethysmograph. The outer two electrodes deliver a high-frequency current to the limb. The voltage drop across the limb is measured between the two inner electrodes.

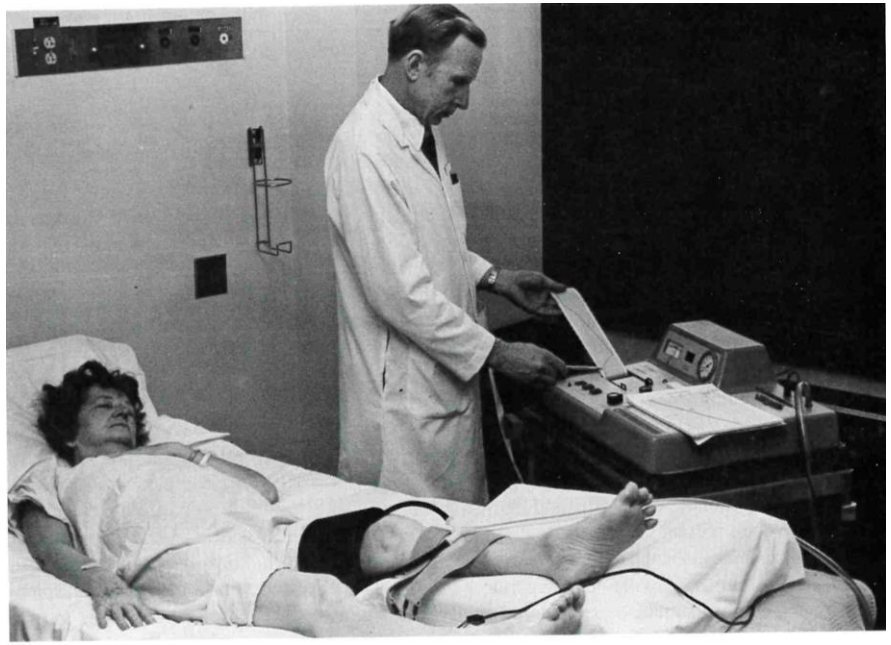


Fig. 51-10. Screening a patient 4 days after aortofemoral reconstruction. The normal tracing excludes thrombosis in major veins with 99% certainty.

Pneumatic Segmental Plethysmography

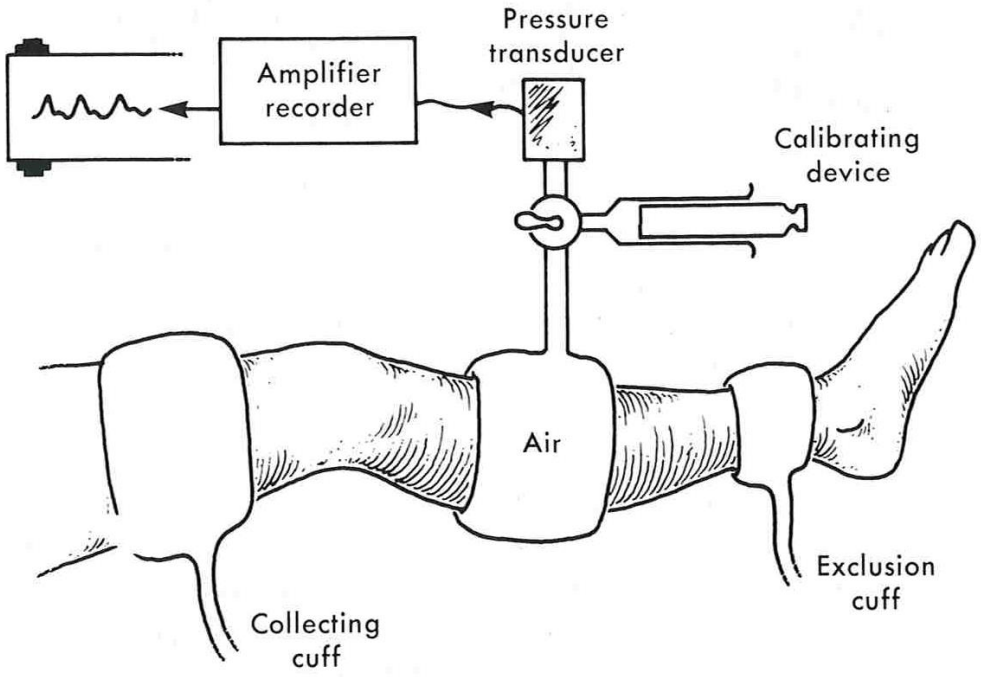
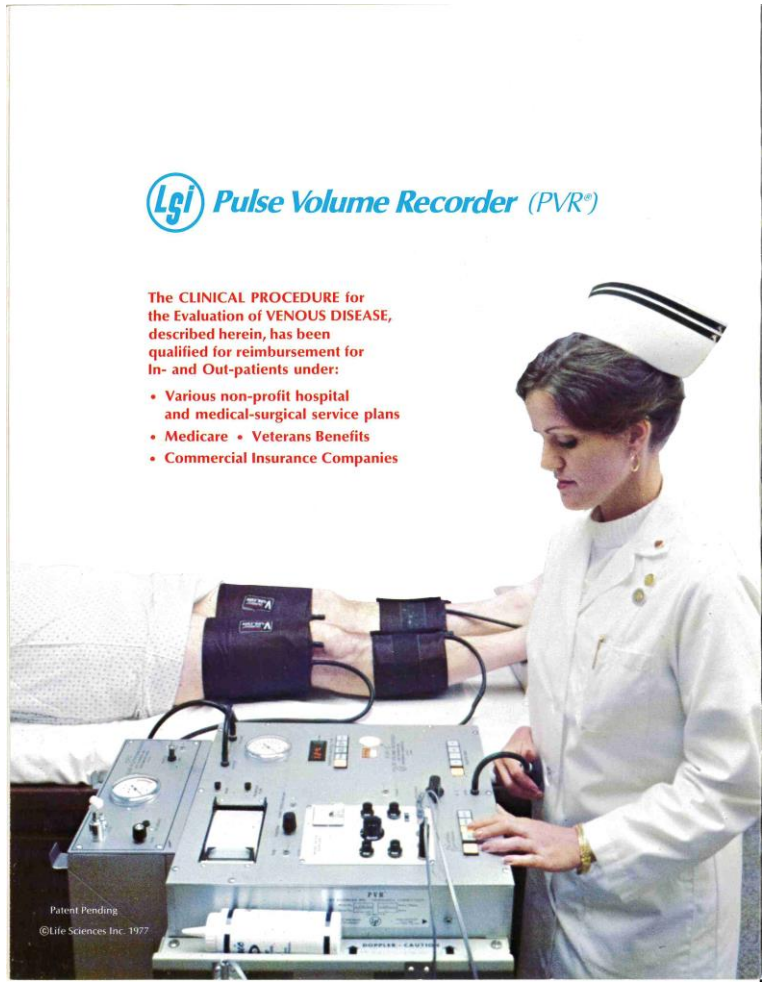
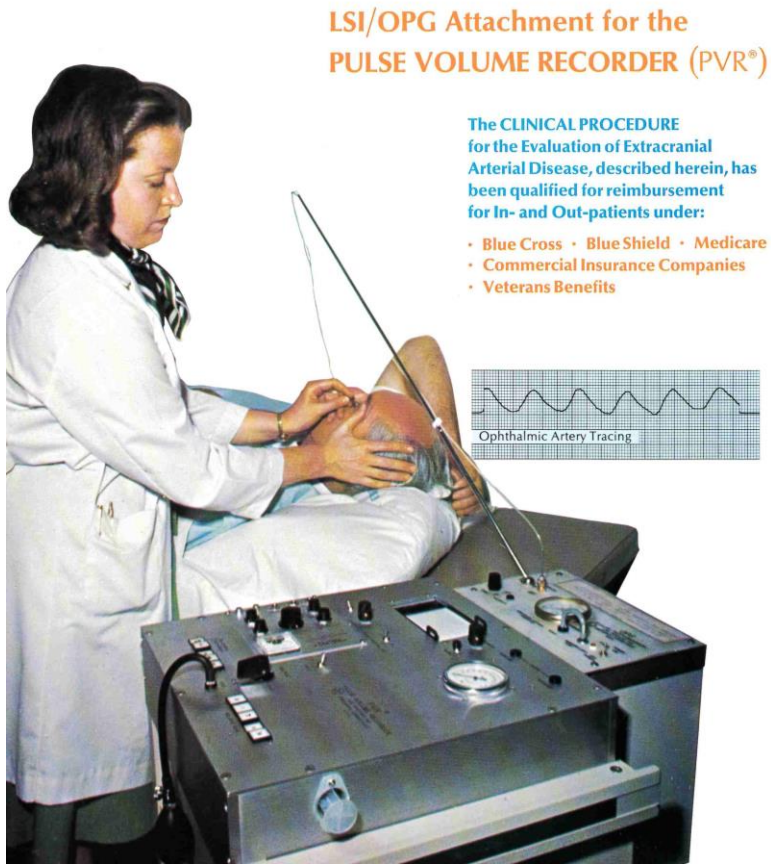
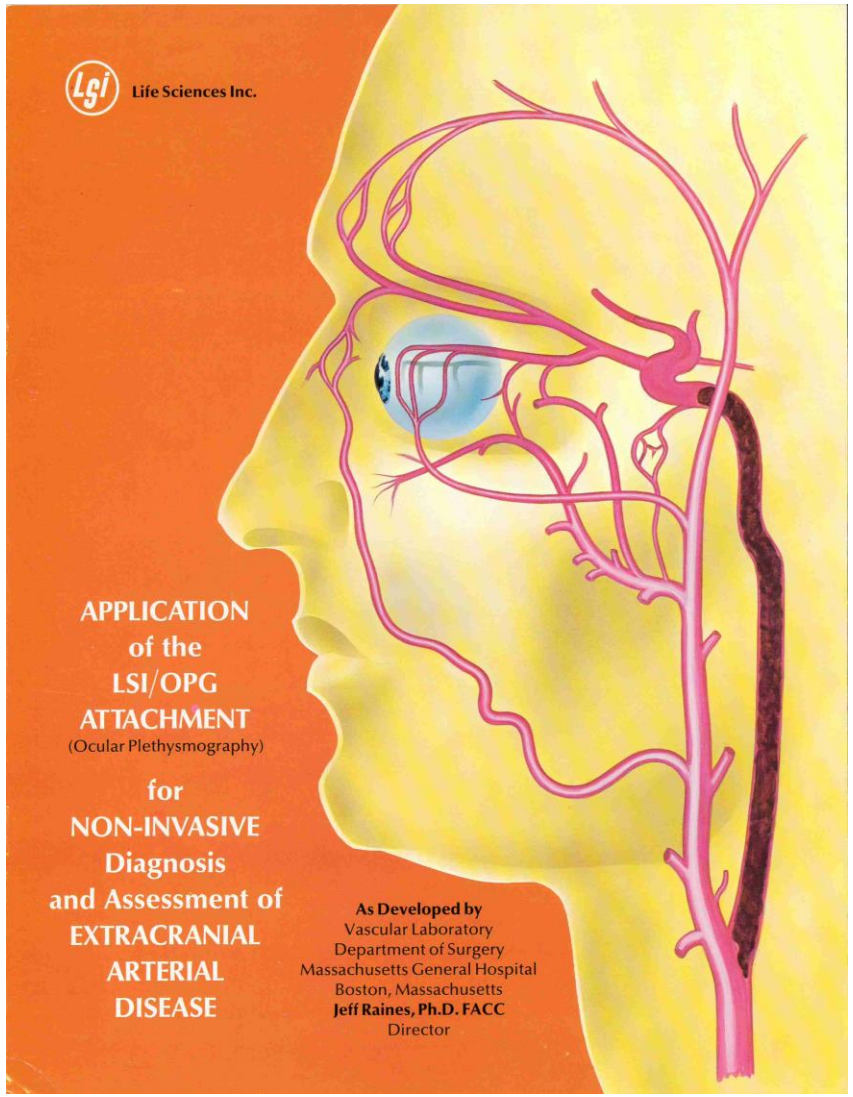


Fig. 8-3. Segmental air plethysmograph. The air-filled cuff is filled to a predetermined pressure to maintain good contact with the limb. Changes in limb volume produce corresponding changes in the air pressure within the cuff.



Ocular Plethysmography

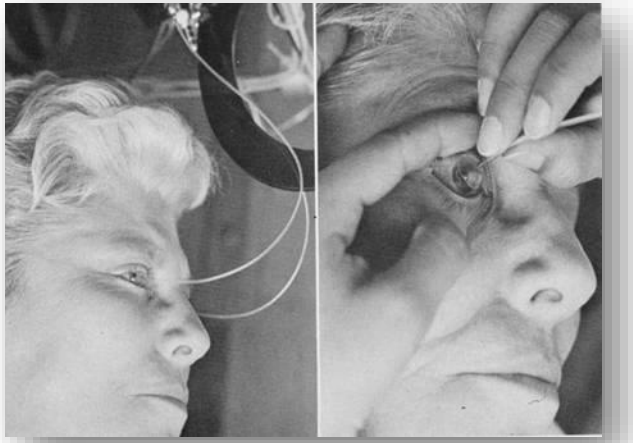


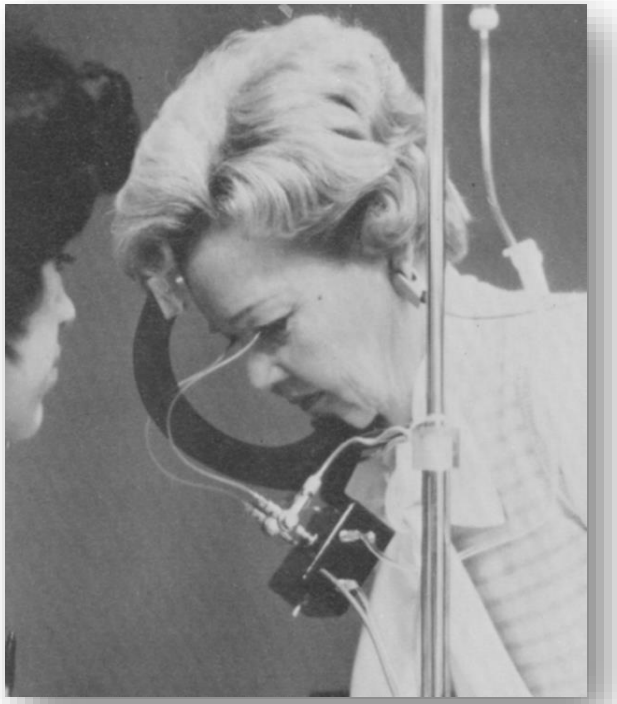


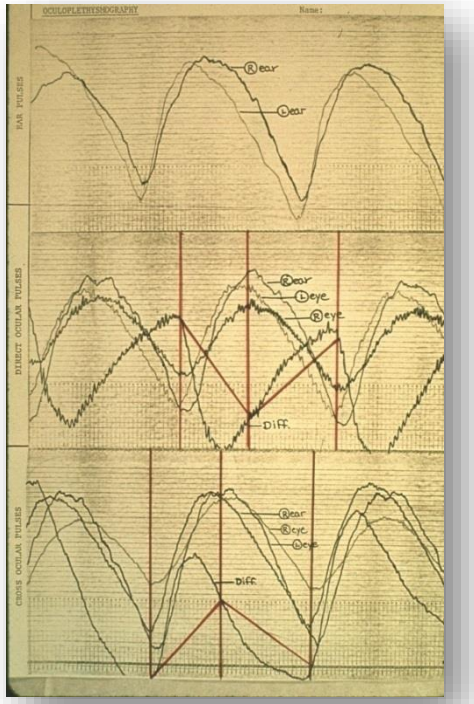
Indirect Vascular Testing

Extracranial Cerebrovascular

Periorbital Doppler



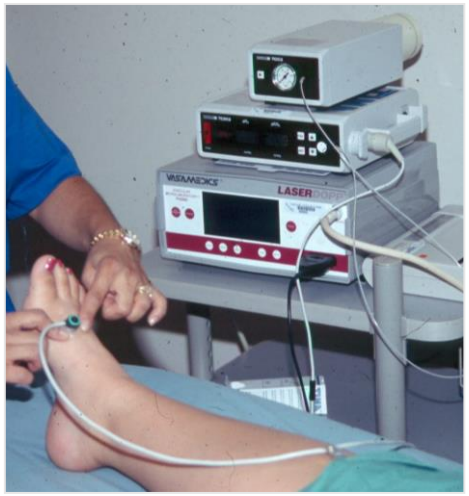




Oculoplethysmography (OPG)

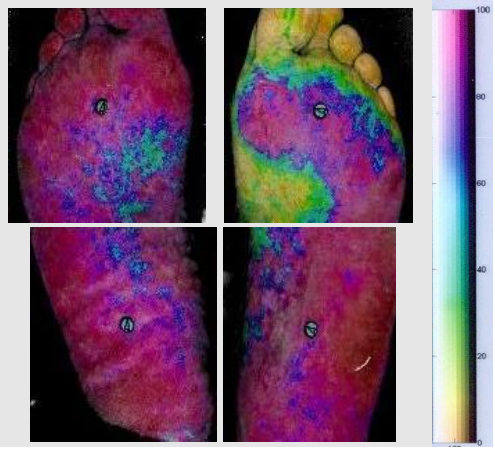
Physiologic Testing

- Doppler waveforms, photoplethysmography, cuff pressure measurements
- Transcutaneous partial pressure of oxygen ($TcPO_2$)
- Laser Doppler skin perfusion pressure
- Near infrared spectroscopy
- Hyperspectral imaging

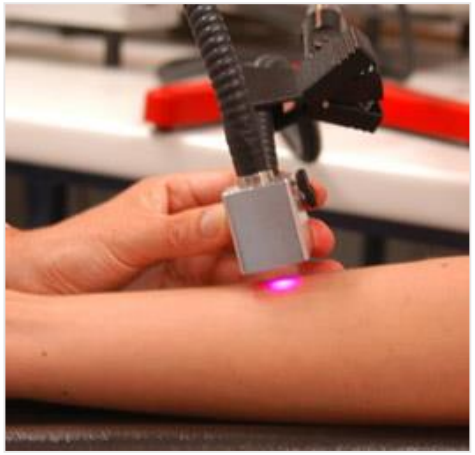


Transcutaneous oxygen partial pressure

Laser Doppler

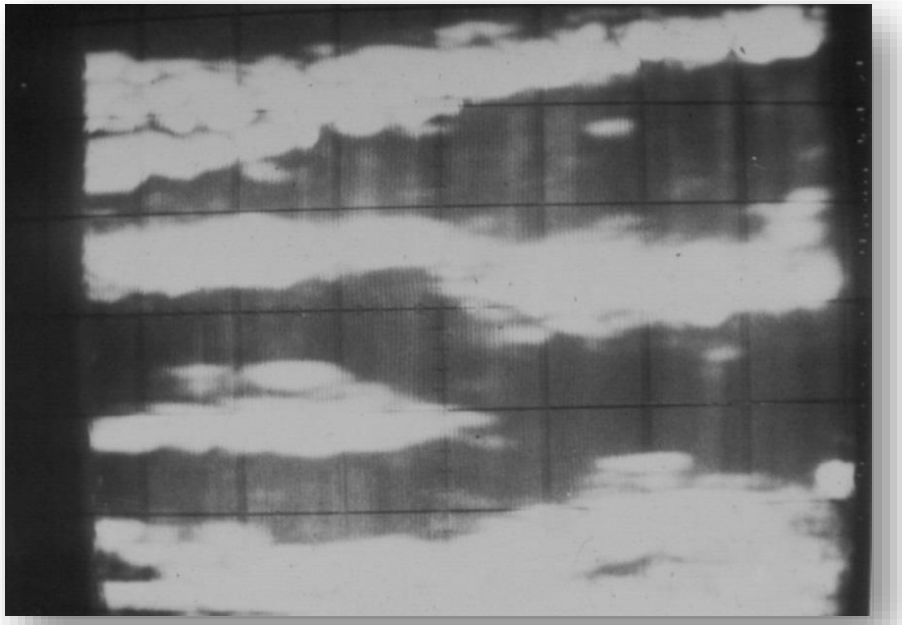


Hyperspectral imaging



Near infrared spectroscopy

“Duplex” Ultrasound Concept



B-mode Imaging

Define anatomy and pathologic changes

+

Pulsed Doppler

Detect and characterize flow patterns


gettyimages
Hulton Archive
2696205


MOTOROLA

ATL Ultrasound

Ultramark 4
1984-1996
general-purpose
non-color-flow scanner
>12,000 produced
$30,000 to $60,000

HDI 3000
introduced in 1994
fourth generation digital ultrasound technology
“Redesigned to be compact and lightweight”
(380 pounds)

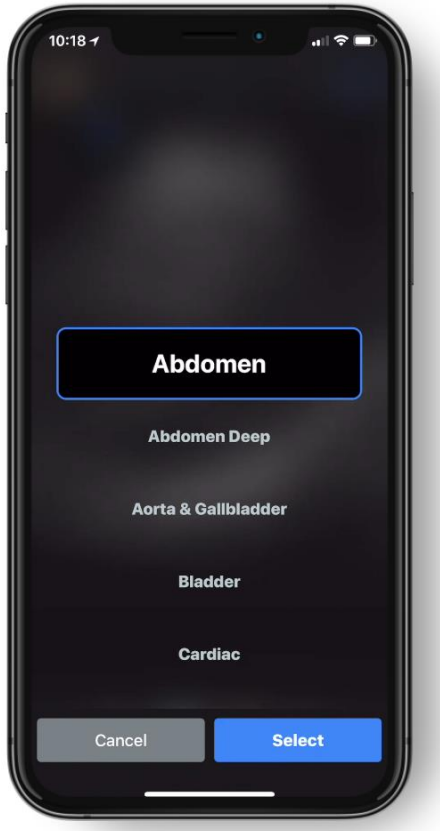
HDI 5000
introduced in 1997
$220,000 to $275,000

Technology of 2022

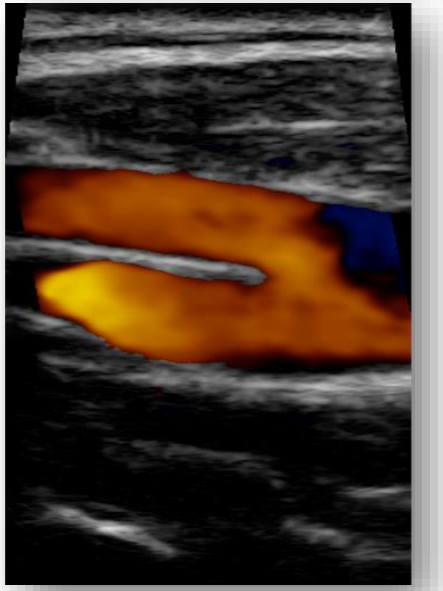
- Over half century of engineering innovation
  - Human factors – improved operator interface
  - Standardized, intuitive controls
  - Minimal training requirement
  - Compatible with legacy technology
- Sturdy, dependable continuous wave Doppler flow detectors used for bedside applications and vascular lab

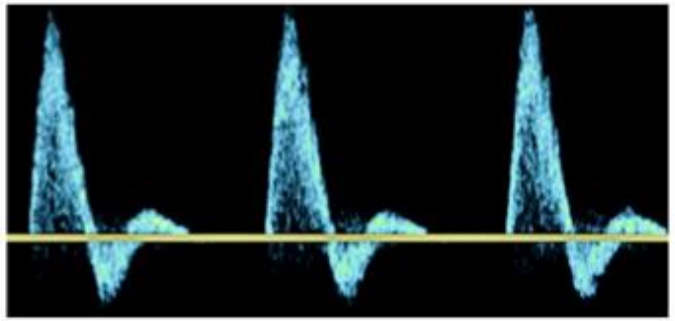
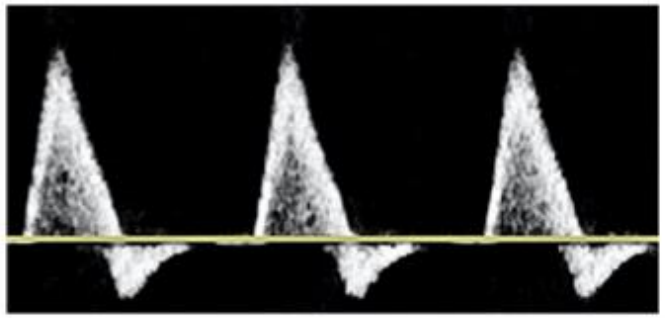
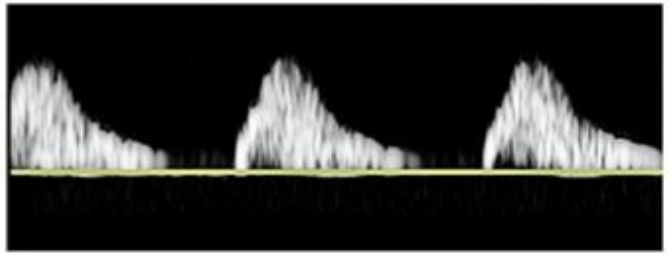
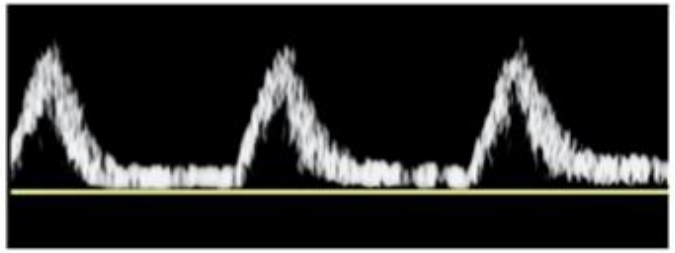

FLIGHT DIRECTOR
APCOM
OPS PLANNER
TOPO
EVA
BME
SURGEON
POSN 4288
POSN 4278


Scan
Theo
Smith, Dana
+ 2
Garcia, Emily
+ 2
Jones, Sarah


10:18
Abdomen
Abdomen Deep
Aorta & Gallbladder
Bladder
Cardiac
Cancel
Select


B
+30.8
cm/s
-30.8



Major descriptor	Major descriptor terms and definitions	Waveform figure
PHASICITY	**Multiphasic** *Previous alternate terms: triphasic; biphasic* Waveform crosses the zero-flow baseline and contains both forward and reverse velocity components.	 
	Monophasic Waveform does not cross the zero-flow baseline throughout any part of the cardiac cycle; blood flows in a single direction. *Note*: if the waveform does not cross the zero-flow baseline it is considered monophasic.	 

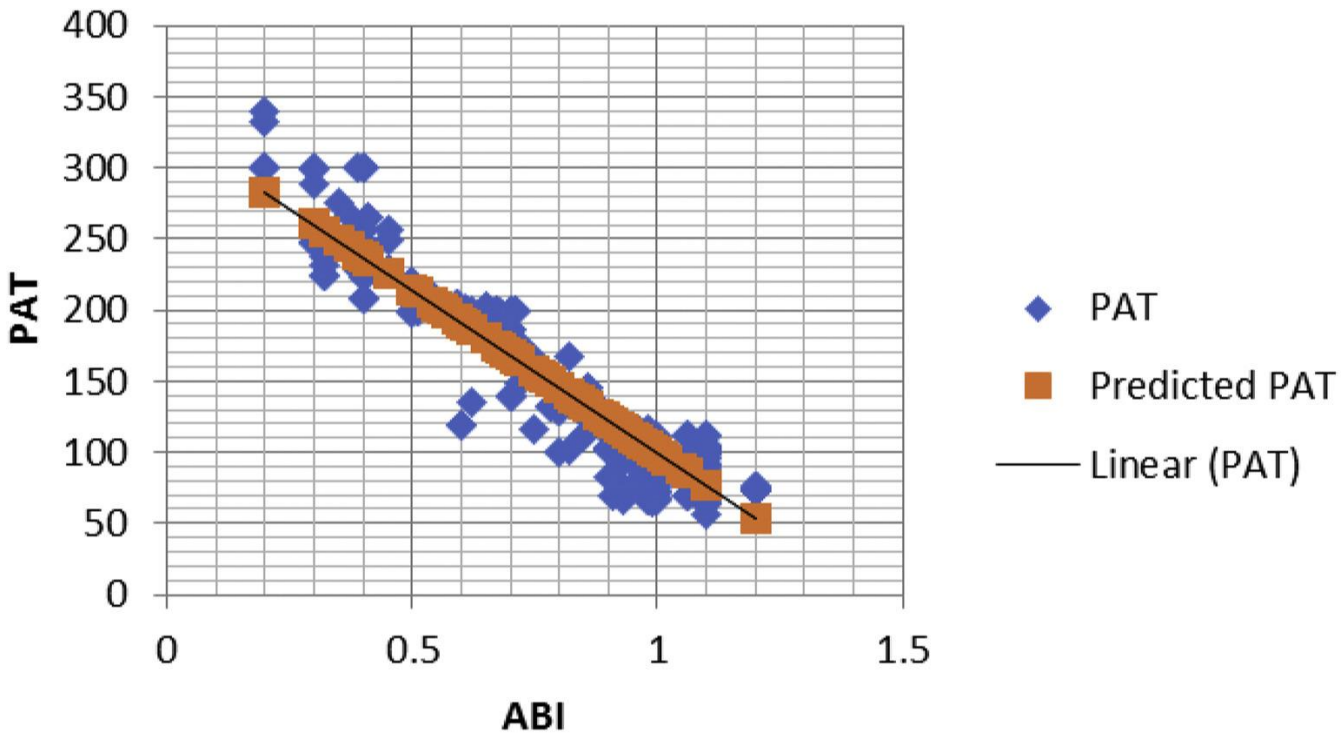
Modern Pioneer

New clinical application for established duplex technologies

- Acceleration time - use of duplex scanning as an indirect test for patients with chronic limb threating ischemia

Jill S. Sommerset, RVT

Pedal Acceleration Time α Ankle/Brachial Index



- PAT measurements do not require additional resources
- PAT not affected by medial calcinosis and vessel incompressibility
- Provides objective perfusion measurement at level of the foot
- Correlation of PAT and ABI
- Cuff pressure measurements obsolete?

Role of Clinical Judgment

- Consider clinical circumstances
- Test results may vary depending of the phase of the illness
- Confounding effects of medications, physiologic status, or comorbidities
- Duplex scanning can provide information about large vessel patency--which helps determine if there is a role for surgery or interventions

Diagnosis:
Non-freezing cold injury, “trench foot”

Use of vasopressors without hemodynamic monitoring

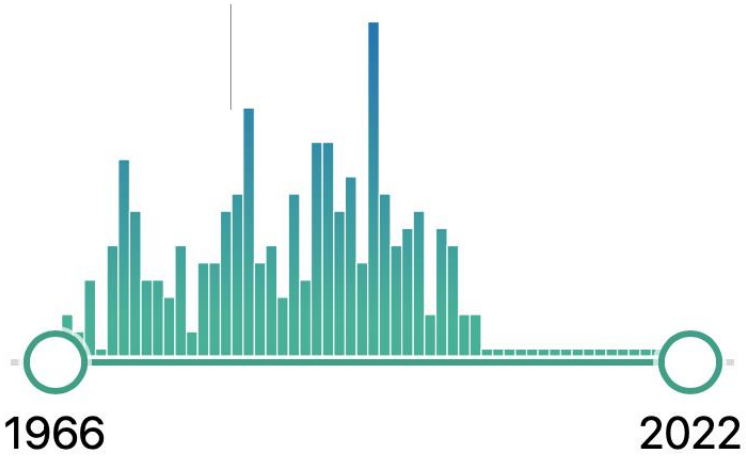
Sufficient Information?

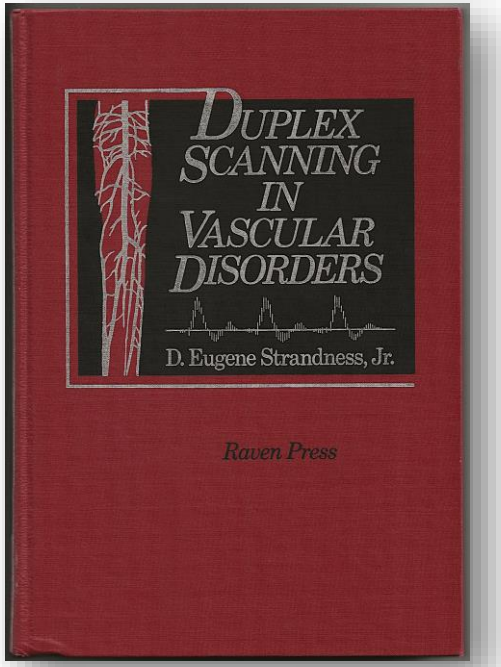
	Duplex scanning	Physiologic testing
• Identify and characterize:		
• Occlusions	✓	⊘
• Stenoses	✓	⊘
• Aneurysms and pseudoaneurysms	✓	⊘
• Arteriovenous fistulae	✓	⊘
• Treatment planning		
• Anatomic level of disease	✓	⊘
• Decision to treat		
• Surveillance	✓	⊘
• Serial assessment		
• Access for peripheral interventions	✓	⊘

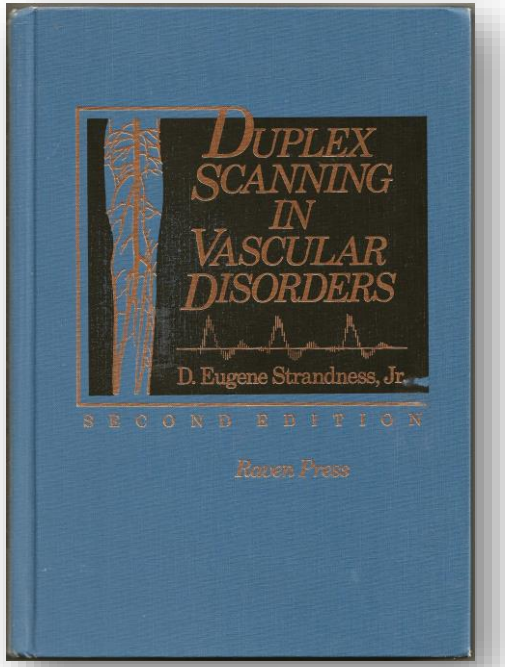
duplex OR ultrasound OR ultrasonic AND Strandness DE [AU]

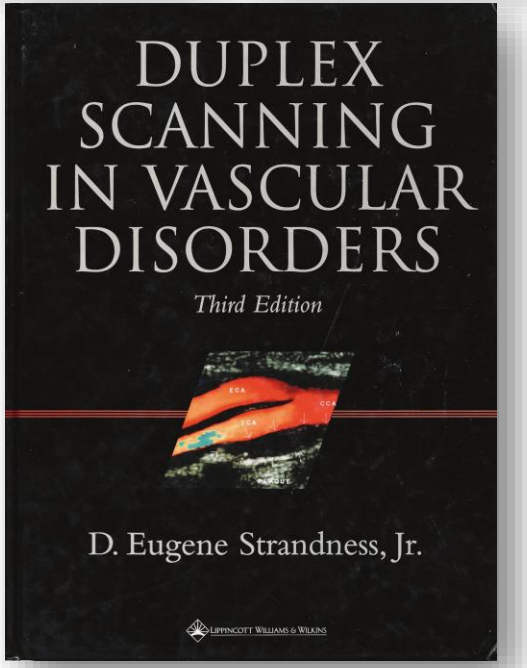
234 papers written by Dr. Strandness on duplex scanning

RESULTS BY YEAR









"Duplex Imaging is All I Really Need"

STRANDNESS SYMPOSIUM

STRANDNESS.ORG