

ship between volume changes in the eye and the corresponding change in intraocular pressure, worked out by Friedenwald (74).

The intraocular dynamics measured by tonometry and tonography are not always constant, but may vary somewhat, depending on the individual and the time of the day at which they are measured (150, 186, 55, 56, 24). The relationship between episcleral venous pressure and changes in other body parameters such as systemic blood pressure or body position have been studied, but their relationship has not been consistently and clearly established (40, 77).

84. Goldmann, H.: Die Kammerwasservenen und das Poiseuille'sche Gesetz. *Ophthalmologica* 118: 496, 1949.

This is a mathematical paper which considers the relationship between the intraocular pressure and the pressure in the various branches of its anatomic drainage system which include Schlemm's Canal, the aqueous veins, and the episcleral veins. Calculations are based on the application of Poiseuille's Law to laminar flow in elliptical tubes.

83. Goldmann, H.: Abflussdruck, Minutenvolumen und Widerstand der Kammerwasserstromung des Menschen. *Documenta Ophthal.* 5/6:278, 1951.

The relationship between the pressure in the eye, the pressure in the episcleral veins outside the eye, the resistance to outflow of fluid from the eye, and the flow rate from the eye is given as a simple formula which is analogous to Ohm's Law. This equation, "Goldmann's Equation," is well accepted among ophthalmologists. The paper also contains descriptions of noninvasive methods for measuring the episcleral venous pressure and the outflow rate of aqueous humor from the eye.

174. Schiotz, H.: Ein Neuer Tonometer; Tonometrie. Archiv. F. Augenh. 52: 401, 1905.

This is the first description of the Schiotz tonometer which is still the standard instrument for the noninvasive measurement of the intraocular pressure.

85. Goldmann, H.: A New Applanation Tonometer. Glaucoma, Transactions of the Second Conference. Josiah Macy, Jr. Foundation, p. 167, 1956.

Dr. Goldmann describes the "Goldmann Applanation Tonometer" which is now recognized as the most accurate noninvasive instrument for the measurement of intraocular pressure, against which other methods are calibrated.

142. Mackay, R. S., Marg, E. and Oechsli, R.: Automatic Tonometer with Exact Theory. Science 131:1668, 1960.

The Mackay-Marg electronic tonometer is described. It is an accurate instrument for measurement of intraocular pressure noninvasively. It has the advantage that it is self-recording, and it has been used by Moses (153) in performing tonography as well.

58. Durham, D. G., Bigliano, R. P., Masino, J. A.: Pneumatic Applanation Tonometer. Tr. Amer. Acad. Ophthal. and Otol. 69:1029, 1965.

A new tonometer is introduced which may be used against the sclera instead of against the cornea and does not require topical anesthesia. Like the Mackay-Marg tonometer, the Durham tonometer is self-recording.

89. Grant, W. M.: Tonographic Method for Measuring the Facility and Rate of Aqueous Flow in Human Eyes. Arch. Ophthal. 44:204, 1950.

Grant introduces tonography, which is a noninvasive method of measuring the resistance to outflow of the aqueous humor of the eye. He uses an electronic Schiötz tonometer to make a continuous pressure recording of the intraocular pressure for four minutes. This pressure curve, along with the Friedenwald nomogram of scleral rigidity, is used to calculate the resistance

to outflow, R. Assuming a value for episcleral venous pressure, he calculates the rate of outflow of the eye.

128. Langham, M. E. and Maumenee, A. E.: The Diagnosis and Treatment of Glaucoma Based on a New Procedure for the Measurement of Intraocular Dynamics. *Tr. Amer. Acad. Ophthal. and Otol.* 68:277, 1964.

Langham introduces a new method for measuring the resistance to outflow of aqueous humor from the eye. He applies a suction cup contact lens to the eye for a few minutes, and after removal, follows the rate of decrease of intraocular pressure by Goldmann applanation tonometry. Suction cup analysis, as Langham's method is called, does not offer any advantages over Grant's method and is more cumbersome to carry out.

153. Moses, R. A.: Constant Pressure Applanation Tonography with the Mackay-Marg Tonometer. *Arch. Ophthal.* 6:20, 1966.

Moses introduces a method of measurement of the resistance to outflow of aqueous humor from the eye which offers the greatest likelihood of being applicable to space flight.

74. Friedenwald, J. S.: Standardization of Tonometers: Decennial Reports by the Committee on Standardization of Tonometers. Chapter VII, American Academy of Ophthalmology and Otolaryngology, 1954.

This important report gives the most recently accepted values of the relation between volume and pressure in the living human eye, expressed as the "Friedenwald Nomogram."

150. Miller, D.: The Relationship Between Diurnal Tension Variation and the Water-Drinking Test. *Amer. Journal Ophthal.* 58:243, 1964.

A simple water-drinking test is described from which the height of the diurnal variation in intraocular pressure may be determined.

186. Thomassen, T. L., Perkins, E. S. and Dobree, J. H.: Aqueous Veins in Glaucomatous Eyes. *Brit. Journal Ophthal.* 34:221, 1950.

The authors discuss the variation in episcleral venous pressure which occur in a diurnal fashion and which they believe to cause the diurnal variation in intraocular pressure. Their opinion has not been substantiated by others, however. This is a poorly written paper, but represents one point of view regarding the cause of diurnal variation.

55. De Rotth, A.: Effect of Changes in Osmotic Pressure of Blood on Aqueous Humor Dynamics. A.M.A. Arch. Ophthal. 52:571, 1954.

The author shows that the diurnal variation in the intraocular pressure is probably due to diurnal variation in the osmolarity of the blood, and hence must be due to different outflow rates from the eye.

56. Drance, S. M.: The Significance of Diurnal Tension Variations in Normal and Glaucomatous Eyes. A.M.A. Arch. Ophthal. 64:494, 1960.

The author shows that diurnal variations in the intraocular pressure are exaggerated in patients with decreased resistance to outflow (glaucoma) and less marked in patients with normal eyes. His work supports the conclusions of De Rotth.

24. Bettman, J. W. Jr., McEwen, W.K., and McBain, E. H.: Venous Pressure Opposing Aqueous Outflow in Patients With and Without Chronic Open Angle Glaucoma. Invest. Ophthal. 5:624, 1966.

By doing tonography and tonometry with noninvasive techniques, the authors show how it is possible to calculate episcleral venous pressure in humans.

40. Brubaker, R. F. and Kupfer, C.: Determination of Pseudofacility in the Eye of the Rhesus Monkey. Arch. Ophthal. 75:693, 1966.

This is an experimental paper using anesthetized monkeys which shows that the pressure measured in the episcleral veins is dependent on the height of the arterial pressure.

77. Gartner, S. and Beck, W.: Ocular Tension in the Trendelenburg Position. Amer. J. Ophthal. 59:1040, 1965.

The intraocular pressure is shown to change an average of 0.42 mm Hg from lying flat to the Trendelenburg position (head 8" below feet). This figure is much less than one would expect on the basis of hydrostatic changes alone.

In addition to the above annotated articles, the following references also contain relevant information: (131, 73, 143, 72, 90, 116, 22, 86, 115).

C.6 Venous Dynamics

The capacitance system adjusts the circulating blood volume and maintains venous return by alterations in tone or distensibility. Though central venous pressure is a major determinant of cardiac output, peripheral or central pressures alone give little information about the tone of the capacitance system because most veins are in a state of partial collapse. An understanding of venous dynamics can be obtained only by studying the reflex responses of the veins to physiologic stress. In this portion of the annotated bibliography, papers are grouped under the following headings:

C.6.1 Review Articles

C.6.2 Reactions to Exercise, Hyperventilation, Deep Breath

C.6.3 Hydrostatic Effects

C.6.4 Effect of Carotid Sinus Stimulation

C.6.5 Effect of Increased Intrathoracic Pressure

C.6.6 Miscellaneous

- a) Response to Autonomic Nervous System Stimulation
- b) Response to Carotid Chemoreceptor Stimulation [®]
- c) Response to Adrenergic Drugs
- d) Venous Tone in Disease States

C.6.1 Review Articles

2. Alexander, R.S.: The Peripheral Venous System. Handbook of Physiology, Circulation. Washington, D.C.: American Physiological Society, 1963, Vol. II, Section 2, Chapter 31, 1075.

See especially for a discussion of the distensibility of veins.

95. Guyton, A.C.: Venous Return. Handbook of Physiology, Circulation Washington, D.C.: American Physiological Society, Vol II, Chapter 32, p. 1099.

A comprehensive analysis of hemodynamic factors which effect venous return.

177. Shepherd, J. R.: Role of the Veins in the Circulation. Circulation 33: 484, 1966.

A discussion of current knowledge and concepts of the control of venous tone.

176. Sharpey-Schafer, E. P.: Venous Tone. Brit. Med. Journal 5267:1589, 1961.

An excellent paper which experimentally documents factors which alter venous tone.

C.6.2 Reactions to Exercise, Hyperventilation, Deep Breath

148. Merritt, F. L. and Weissler, A.M.: Reflex Venomotor Alterations During Exercise and Hyperventilation. Am. Heart Journal 58:382, 1959.

Exercise, deep breath, hyperventilation, passive leg motion, and reactive hyperemia were studied. Only the first three were found to produce consistent venoconstriction. A Ganglionic blocker abolished the response.

173. Samueloff, S. L. et al.: Temporary Arrest of Circulation to a Limb for the Study of Venomotor Reactions in Man. Journal of Applied Physiology 21:341, 1966.

Venoconstriction was demonstrated in response to hyperventilation, deep breath, leg exercise, and breathing 7% CO₂ in oxygen.

26. Bevegord, B. S. and Shepard, J. T.: Changes in Tone of Limb Veins During Supine Exercise. *Journal of Applied Physiology* 20:1, 1965.

General peripheral venoconstriction was shown to occur during leg exercise. Forearm venoconstriction associated with leg exercise was not effected by simultaneous arm exercise. It was concluded that the local metabolic effects of exercise do not effect venous tone. No forearm venoconstriction occurred in a patient who had previously undergone a cervical sympathectomy for relief of vascular symptoms.

80. Gauer, O.H. and Thron, H. L.: Postural Changes in the Circulation. Handbook of Physiology, Circulation. Washington, D. C.: American Physiological Society, 1963, Vol. III, Chapter 67.

An excellent review of hydrostatic effects on hemodynamics including a discussion of the hydrostatic indifference point and the response of the veins to passive tilt.

207. Wood, J. E. and Eckstein, J. W.: A Tandem Forearm Plethysmograph for Study of Acute Responses of the Peripheral Veins of Man. *Journal Clin. Invest.* 37:41, 1958.

Environmental and local cooling were shown to produce peripheral venoconstriction. Pooling blood in the legs by 30° head-up tilt and cuffs (about 750cc sequestered) produced prompt arteriolar constriction; venoconstriction took place later and took longer to reach a maximum. It was concluded that the threshold to arterial response was lower than that to venous response.

170. Salzman, E. W. and Leverett, S. D. Jr.: Peripheral Venoconstriction During Acceleration and Orthostasis. *Circulation Research* 4:540, 1956.

Tilt table studies showed less clear cut venoconstriction than +G_z acceleration, suggesting a threshold factor in the constrictive response to venous pooling.

172. Samueloff, S. L., Browse, N. L. and Shepherd, J. T.: Response of Capacity Vessels in Human Limbs to Head-Up Tilt and Suction on Lower Body. *Journal of Applied Physiology* 21:47, 1966.

Head-up tilt and suction to the lower body produced transient increases in venous tone and sustained constriction of resistance vessels. If the stimulus was applied gradually, there was no response of the capacitance system. It was concluded that the veins played no active role in the response to gravitational stress.

171. Salzman, E. W.: Reflex Peripheral Venoconstriction Induced by Carotid Occlusion, *Circulation Research* 5:149, 1957.

Carotid sinus hypotension produced venous and arteriolar constriction "similar in time course and magnitude". Carotid sinus denervation abolished the venous response, deafferentation of the aortic arch by cervical vagotomy increased it.

38. Browse, N. L., Donald, D. E., and Shepherd, J. T.: Role of the Veins in Carotid Sinus Reflex. *American Journal of Physiology* 210:1424, 1966.

Carotid sinus hypotension was shown to produce a marked constrictor response of the resistance vessels, but only a minimal increase in venous tone. Stimulus-response curves of resistance and capacity vessels were determined by graded stimulation of the lumbar sympathetic chain. The average arterial response to hypotension was equivalent to sympathetic stimulation at a rate of 3 impulses/sec, the venous to 0.2 impulses/sec.

27. Bevegord, B. S. and Shepherd, J. T.: Circulatory Effects of Stimulating the Carotid Arterial Stretch Receptors in Man at Rest and During Exercise. *Jour. Clin. Invest.* 45:132, 1966.

Stimulation of carotid sinus stretch receptors by applying negative pressure to the neck vessels did not result in venous dilation. Exercise caused venoconstriction despite carotid stretch receptor stimulation. The reduction in

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blood pressure and heart rate were related linearly to the stimulus.

C.6.5 Effect of Increased Intrathoracic Pressure.

196. Watson, W. E.: Venous Distensibility of the Hand During Valsalva's Maneuver. Brit. Heart Journal 24:26, 1962.

A marked decrease in venous distensibility was produced by the Valsalva maneuver and demonstrated by pressure/volume curves of isolated venous segments.

195. Watson, W. E., Smith, A. C. and Spalding, J.M.K. Transmural Central Venous Pressure During Intermittant Positive Pressure Respiration. Brit. Journal Anaesth. 34:278, 1962.

Increased intrathoracic pressure stimulated reflex peripheral venous constriction to maintain central venous pressure in the face of obstruction to venous return. Maintenance of central venous pressure could not be accomplished in patients with polyneuritis and spinal cord transections.

C.6.6 Miscellaneous

a) Response to Autonomic Nervous System Stimulation

167. Ross, J. C., Hickman, J. B., Wilson, W.P., and Lowenback, H.: Reflex Venoconstrictor Responses to Strong Autonomic Stimulation. Am. Heart Journal 57:418, 1959.

Electroconvulsive shock therapy in patients premedicated with thiopental and succinylcholine was shown to increase central venous pressure within 10 seconds. It was felt that this rapid response indicated peripheral venous constriction by a reflex rather than a humoral mechanism.

(See also (38) above for lumbar sympathetic stimulation.)

b) Response to Carotid Chemoreceptor Stimulation

37. Browse, N. L. and Shepherd, J. T.: Response of Veins of Canine Limb to Aortic and Carotid Chemoreceptor Stimulation. American Journal of Physiology 210:1435, 1966.

Stimulation of the carotid and aortic chemoreceptors with cyanide caused both increases and decreases in venous tone. Atropinization did not abolish the responses which were therefore considered due only to variation in sympathetic vasoconstrictor activity.

c) Response to Adrenergic Drugs

62. Eckstein, J. W., Wendling, M. G., and Abboud, F. M.: Forearm Venous Responses to Stimulation of Adrenergic Receptors. J. Clin. Invest. 44:1151, 1965.

Infusion of Isuprel, a beta adrenergic stimulus, was shown to have no effect on veins. Epinephrine which stimulated both alpha and beta receptors caused venoconstriction only.

(See also (2, 95, and 176) above for further discussion of humoral agents).

d) Venous Tone in Disease States

49. Caliva, F. S. et al.: Digital Hemodynamics in the Normotensive and Hypertensive States. II. Venomotor Tone. Circulation 28:421, 1963.

Increased venous tone was demonstrated to be part of the overall increase in peripheral vascular resistance in hypertension.

(See also (177) above for a discussion of congestive heart failure, beriberi, and anemia.)

In addition to the above annotated articles, the following references also contain relevant information: (114, 161, 178, 120, 188, 78, and 98.)

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APPENDIX D

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15. Anliker, M. and Wolternik, L.: Transmission Velocity of Induced Pulse Waves. *Fed. Proc.* 25:1156, 1966.
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APPENDIX E

RESULTS OF QUESTIONNAIRE MAILING

In the course of the program we have prepared and mailed 226 form letters and questionnaires, copies of which are shown in Figures E-1 and E-2. These were sent to individuals whom we believed to be active in the relevant areas of the cardiovascular function and measurement field. The mailing list was compiled from many sources including personal knowledge of our staff, individuals uncovered during the literature search, those suggested by respondents to the questionnaire and individuals brought to our attention by the various people we have contacted and visited in conjunction with this program.

The results of this mailing were most gratifying in that we not only received an overwhelming response (109 replies out of the 226 questionnaires sent), but we also obtained much useful information in the form of specific ideas and suggestions, relevant publications and work, and additional individuals to contact.

The following list summarizes both the more significant and the typical questionnaire replies.

<u>NO.</u>	<u>NAME AND ADDRESS</u>	<u>AREA OF WORK AND SUGGESTIONS</u>
1	Robert S. Alexander Albany Medical College Albany, N.Y.	Has done extensive work in central and local controlling mechanisms and their relationship to basic properties of the venous system. Feels venous pressure is not a homogeneous entity and, therefore, that the project is "misdirected".
2	Julia T. Apter Presbyterian St. Luke's Hospital 1753 W. Congress Pkwy Chicago, Illinois	Has studied visco-elastic properties of veins with experiments guided by a three parameter model. The parameters are obtained experimentally, fitted into the differential equations of

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Subject: Venous Pressure Measurements

The National Aeronautics and Space Administration would like to find out what happens to the venous blood pressure of astronauts during space flight. We are conducting a program for NASA, under contract NAS W-1559, to locate, evaluate, and develop techniques for noninvasive measurements of venous pressure. We feel that you can help us in our role as a collecting agency for suitable measurement techniques and ideas. The purpose of this letter is to enlist your aid in bringing to our attention any new measurement techniques, on which you may be working or with which you may be familiar, so that they may be evaluated and included in the study. Any ideas or data you supply would be given full credit in any resulting publications or projects. Furthermore, complete protection will be afforded any proprietary information supplied to us.

As part of the program, we are conducting a literature search and developing an annotated bibliography of medical and engineering works relevant to venous pressure measurement. In order to make this bibliography as up-to-date as possible, as well as to insure that we include all promising work, we have undertaken to contact people in the field, such as yourself, and request that they fill out and return the attached short questionnaire. Since you would be undoubtedly interested in the results of our literature survey, we would be happy to make a copy of our final bibliography available to you. Incidentally, a prompt reply would help us greatly since we are working on the fairly strict time schedule of the Apollo Application program.

Thank you in advance for your cooperation and assistance.

Sincerely,

James W. Dow, M.D.
Principal Investigator

FIGURE E-1

1. Have you worked with venous pressure measurements?
If so, please describe your experience.

2. If you have any new measurement techniques, on which you may be working or with which you may be familiar, so that they may be evaluated and included in the study.

3. Can you suggest any other people who might be interested in this project?

4. In your opinion, what are the major problems in the study of venous pressure?

5. Name of institution
Date

Thank you for your cooperation and assistance. This material will be sent to you.

Biosystems, Inc.

Venous Blood Pressure Measurement Questionnaire

If address shown is inaccurate,
please correct here.

1. Have you worked in the area of venous pressure control or measurement? Yes No
If so, please describe your work briefly. Use additional sheets if desired. —

2. If you have published or reported any of this work please enclose reprints. If these are not readily available please list the references here.

3. Can you suggest other individuals or organizations who are active in the area of venous pressure measurements?

4. In your opinion which, if any, venous pressure measurement techniques show promise?

5. Name of individual completing the questionnaire _____;

Date _____; Phone No. _____.

Thank you for your assistance. Completed copies of our annotated bibliography will be sent to those who complete and return this questionnaire. If you desire this material please check here _____.

<u>NO.</u>	<u>NAME AND ADDRESS</u>	<u>AREA OF WORK AND SUGGESTIONS</u>
2	Julia T. Apter (cont.)	motion of the model and then used to analyze venous pressure curves. Aim is to find a transfer function.
3	E. O. Attinger Res. Inst. Pres. Hosp. U. of Pennsylvania Philadelphia, Pa.	Has done extensive work in analysis of pressure-flow relations and vessel wall characteristics of the venous and arterial tree. Suggested another individual to be sent questionnaire. Subsequently assisted in this program (See App. A)
4	Hermann Bader Dept. of Pharmacology U. Medical Center Jackson, Miss.	Recommended two names for questionnaire.
5	Ernest Barany Inst. of Pharmacology U. of Uppsala Uppsala, Sweden	Has worked with cannulation of saggittal sinus in monkeys. Pressure breathing with a pressure suit enclosing the monkey and helping expiration. Recommends Erik Linner, Umea University in Sweden who developed a noninvasive method for the small veins on the eye.
6	Henry Barcroft Sherrington Sch. of Physiology St. Thomas Hosp. Med. Sch. London, England	Recommends two other people.
7	G. Octo Barnett, Lab. of Computer Science Mass. General Hospital Boston, Mass.	Recommends two other people.
8	Jan E. W. Beneken Dept. of Physiology & Biophysics U. of Miss. Sch. of Med. Jackson, Miss.	Designing electronic analog computer model of human blood circulation system.

<u>NO.</u>	<u>NAME AND ADDRESS</u>
9	Mr. Anders Dept. of Phys. U. of Uppsala Uppsala, Sweden
10	Stanley E. Dept. of Medicine College of Physicians N.Y., N.Y.
11	Gerhard A. Dept. of Physiology U. of Oklahoma 800 N.E. 13th Oklahoma City
12	Dr. Ellen B. U. of California San Francisco
13	Alan C. Burdette Dept. of Biology U. of Western Ontario London, Ontario
14	Jose L. Duomo Servicio de Fisiologia U. de la Republica Hospital de la Avenida Italia Montevideo, Uruguay
15	Walter Feder Dept. of Medicine U. of Chicago Chicago, Ill.
16	J. D. Fewing Senior Research Dept. of Human Pharmacology U. of Adelaide Adelaide, S. Australia

NO. NAME AND ADDRESS

AREA OF WORK AND SUGGESTIONS

- 9 Mr. Anders Bill
Dept. of Pharmacology
U. of Uppsala
Uppsala, Sweden
Has studied pressure in the intrascleral veins in rabbits and cats and also pressure in the small veins in the eye of cats. Suggests direct cannulations using very thin polyethylene tubes.
- 10 Stanley E. Bradley
Dept. of Med. Columbia U.
College of Phys. & Surg.
N.Y., N.Y.
Has studied effect of gravitation shifts in man, effect of shock in man and dog with special reference to portal venous system and also effect of venal hepatitis on man and dog including splanchnic venous pressure.
- 11 Gerhard A. Brecher
Dept. of Physiology
U. of Oklahoma Med. Ctr.
800 N.E. 13th Street
Oklahoma City, Okla.
Has worked with intravascular venous pressure measurements. Sent reprints. Author of "Venous Return". Suggests Ian Mackay.
- 12 Dr. Ellen Brown
U. of Calif. Med. Ctr.
San Francisco, Cal.
Has done extensive work in venous system. Suggests plethysmographic technique. Sent reprints and bibliography. Suggests two other people.
- 13 Alan C. Burton
Dept. of Biophysics
U. of W. Ontario
London, Ontario, Canada
Suggests digital plethysmography. Sent detailed note explaining approach. Recommends we contact G. Burch.
- 14 Jose L. Duomarch
Servicio de Fisiologia Obstetrica
U. de la Republica
Hospital de Clinicas, Piso 16
Avenida Italia, S/N
Montevideo, Uruguay
Sent two monographs on venous pressure.
- 15 Walter Feder
Dept. of Medicine
U. of Chicago
Chicago, Illinois
Has developed a simple narrow bore plastic tube attached to a needle which would give mean pressure as well as some idea of pulsatile changes.
- 16 J. D. Fewings
Senior Research Off.
Dept. of Human Physiol. & Pharmacy
U. of Adelaide
Adelaide, S. Australia
Has measured venous pressure via a polyethylene catheter introduced into the cephalic veins and connected to a conventional pressure transducer.

- 17 Otto Gauer
Der Freien U. Berlin
Berlin, Germany
Has little confidence that a noninvasive technique of satisfactory accuracy will be found.
- 18 M. Jay Goodkind
Div. of Cardiology
Philadelphia Genl. Hosp.
Philadelphia, Penna.
Has done clinical measurements by cardiac catheterization. Suggests A. Guyton.
- 19 A.D.M. Greenfield et al
Dept. of Physiology
St. Mary's Hosp. Med. Sch.
London W 2, England
Has made measurements of central venous pressure during lower body negative pressure suction manoeuvre using catheters and electrical pressure transducers. Results will be published shortly. Knows of no promising noninvasive methods.
- 20 Warren G. Guntheroth
Dept. of Pediatrics
U. of Wash. Sch. of Med.
Seattle, Washington
Worked in the area of venous return. Has been studying the superior vena cava with simultaneous distending pressure and diameter and flow in relation to exercise. Are using silastic tubing and silastic balloons in the pleural cavity. Has worked reasonably well. See reprint.
- 21 Chester Hyman
Prof. of Physiology
U. of S. California
School of Medicine
Los Angeles, Calif.
Sent patent and reprint. Suggested other articles of interest.
- 22 John W. Irwin
Mass Eye & Ear Infirmary
243 Charles Street
Boston, Mass.
Working with pressures of microcirculation. Developing a method for securing dynamic pressure-grams on arterioles of approx. 50 micra. Suggested five other individuals.
- 23 John Jones
U. of Nebraska
College of Medicine
Omaha, Nebraska
Has measured venous pressure on hundreds of patients using simple infusion set.
- 24 R. T. Kado
Space Biology Lab
Brain Research Inst.
U. of California
Los Angeles, Calif.
Has used strain gage pressure transducer with catheter miniaturized for intra-vascular use. Suggests two other sources.
- 25 H. Kanai
Dept. of Electrical Engrg.
Sophia U. Chiyoda-Ku
Tokyo, Japan
Has worked on pulsatile blood pressure measurement by catheter method. Suggests optical method, the infrared plethysmograph.

E. Kinnen
Dept. of E
U. of Roches
Rochester,

H. H. Kopal
Mass Genera
Fruit Street
Boston, Mas

Chauncey D.
U. of Califo
San Francis
San Francis

Erik Linner
Dept. of Opt
University
U. of Umea,

Ian F. S. M
Baldorioty
Calle Diez
Santurce, P

Frank Macri
Nat. Inst. of
& Blindness
N.I.H., Bet

John M. Mor
Dept of Sur
Tufts U. Sch
Boston, Mas

Raymond Mur
Indiana Uni
Cardiopulmo
6570 AMRL
W.P.A.F.B.,

Y. Nose
Dept. of Art
Cleveland C
2020 E. 93rd
Cleveland,

- 6 E. Kinnen
Dept. of Elect. Engrg.
U. of Rochester
Rochester, N.Y. Working with venous flow, particularly pulmon-
ary venous flow. Suggested two other individ-
uals.
- 7 H. H. Kopald
Mass General Hospital
Fruit Street
Boston, Mass. Measured venous pressure by use of inlaying
polyethelene catheters in dogs. Suggested
another person.
- 8 Chauncey D. Leake
U. of California
San Francisco Med Ctr.
San Francisco, Calif. Suggests water manometer and cuff.
Recommends another person.
- 9 Erik Linner
Dept. of Ophthalmology
University Hospital
U. of Umea, Umea, Sweden Has developed a method for measuring the episcl-
eral venous pressure in human beings and rabbits.
Feels that this is a suitable technique for non-
invasive measurements of the episcleral venous
pressure.
- 10 Ian F. S. Mackay
Baldorioty Plaza 1404
Calle Diez De Andino 212
Santurce, Puerto Rico Has done extensive pertinent work. Has assisted
significantly in this program (See Appendix B).
- 11 Frank Macri
Nat. Inst. of Neurol. Diseases
& Blindness Clinical Center
N.I.H., Bethesda, Maryland Has measured venous pressure of the eye and sug-
gests microcannulation techniques.
- 12 John M. Moran
Dept of Surgery
Tufts U. School of Medicine
Boston, Mass. Familiar with venous pressure measurements in
clinical applications to major surgery and post-
operative management. Aspects of percuta-
neous catheterization have been studied clinic-
ally. Knows of no noninvasive technique.
- 13 Raymond Murray
Indiana University
Cardiopulmonary Lab,
6570 AMRL (MRBB)
W.P.A.F.B., Ohio Has measured central venous pressure changes
during environmental stresses. Suggests height
of blood column in neck veins.
- 14 Y. Nose
Dept. of Artificial Organs
Cleveland Clinic Found.
2020 E. 93rd Street
Cleveland, Ohio Monitors the venous pressure of the vena cava
(superior-inferior) and the r & l atrium. Use
strain gauge transducers via silicone tubing.

- 35 Jorge Perez-Cruet
Pavlovian Lab.
Johns Hopkins U.
School of Medicine
Baltimore, Md. Has measured venous pressure in dogs, rt. ventricular pressures in dogs and venous pressure in humans. He suggests rt ventricular pressure by direct catheter and also venous pulse waves (osillographic).
- 36 Richard M. Rauch
Smith Kline Instrument Co.
1500 Spring Garden St.
Philadelphia, Pa. Has used catheters and strain gage transducers. Has considered other direct methods. Has also worked with IR pickups similar to ear oximeters. Suggests transcutaneous Doppler flow system, and try to derive pressure from flow.
- 37 S. R. M. Reynolds
P.O. Box 6998
Chicago, Illinois Has measured systemic and venous pressures in the lamb fetus in utero (without gravity pull).
- 38 Robert F. Rushmer
Professor of Physiology
U. of Washington
Seattle, Washington Points out that there appears to be good evidence for a region of partial venous occlusion at the entrance of veins into the thorax. This implies that the peripheral venous pressure is very apt to be substantially different from the venous pressure within the thorax.
- 39 Allen M. Scher
Dept. of Physiol & Biophys.
U. of Washington
School of Medicine
Seattle, Washington Attempted to find venous reflexes, but found none. Suggests another individual.
- 40 Marvin Sears
Prof of Ophthalmology
Yale U. of Medicine
New Haven, Conn. Measured venous pressure in the eye and its outflow channels. Suggested several other people.
- 41 Ewald E. Selkurt, et al
Dept. of Physiology
Indiana U. Sch. of Med.
Indianapolis, Indiana Venous pressure measurement during shock, hemorrhages, A-V fistulas, cardiac function in shock, etc. Feels direct measurement by implanted transducers is best.
- 42 John T. Shepherd
Section of Physiology
Mayo Clinic
Rochester, Minn. Studies on men and dogs using invasive techniques. Suggested two other people.
- 43 Merrill P. Spencer
Virginia Mason Res. Ctr.
1202 Terry Avenue
Seattle, Washington Suggests that a small inflatable chamber, like a plethysmograph over an extremity might be calibrated in terms of resistance so that there might be a change in resistance when the veins are emptied as the pressure of the chamber is elevated.

Robert L. V.
Dept. of Ph
U. of Washi
Seattle, W

J. Weinman
Rogoff Lab.
The Hebrew
Hadassah M
Jerusalem,

J. R. Whit
Instrument
2121 K Str
Washington

Fred Wiener
IBM, Advan
2651 Strong
Yorktown H

Travis Wins
4041 Wilsh
Los Angeles

J. Edwin W
U. of Virgin
Hospital B
Charlottesv

Robert L. Van Citters
Dept. of Physiology & Biophysics
U. of Washington Sch. of Med.
Seattle, Washington

Has developed a system for telem-
etry of blood flow and blood pressure
in the arterial system. Feels it is
applicable to the venous system with
small modifications.

J. Weinman
Rogoff Lab. for Med. Elect.
The Hebrew U.
Hadassah Med. School
Jerusalem, Israel

Feels problem is very complicated and not
immediately soluble. Suggests photoplethys-
mographic recording of effects of Valsalva
maneuver. Gives noninvasive recording of chang-
ing venous vasomotor tone.

J. R. Whiteman
Instrumentation Field Sta.
2121 K Street, N.W.
Washington, D.C.

Suggests a form of venous occlusion plethysmo-
graphy.

Fred Wiener
IBM, Advanced Systems Dev. Div.
2651 Strong Blvd.
Yorktown Heights, N.Y.

Worked on models of wave propagation
in the pulmonary circulation relating
the oscillation of venous pressure and
flow to right ventricular pressure
propagated through the pulmonary capill-
aries into the veins.

Travis Winsor
4041 Wilshire Blvd
Los Angeles, Calif.

Normal values and establishment of reference
levels. Also venous pressure in children.
Suggested contacting Burch et al.

J. Edwin Wood III
U. of Virginia
Hospital Box 146
Charlottesville, Va.

Suggests measurement of the natural volume of
the extremity followed by deflation of the veins
to minimal volume, then re-inflation of veins
by congestion techniques through a series of
pressures with simultaneous measurement of volume.
Has done work in plethysmography. Suggests four
other individuals.

APPENDIX F.

SUMMARY OF CONTACTS AND VISITS

<u>No.</u>	<u>Individuals</u>	<u>Affiliation</u>	<u>Conducted By</u>	<u>Type of Contact*</u>	<u>Discussions & Results</u>
1.	Akers, W.W. & Bourland, H.M.	Rice Univ. Houston, Tex.	L. Stark	V	Discussed modeling of venous pulse, importance of venous pressure to left heart bypass work. Suggested references and other contacts.
2.	Attinger, E.O.	Presbyterian Univ. of Penn. Philadelphia, Pa.	R. Brubaker, D. Worthen, S. Molner, L. Young, J. Pines, J. Newman	P, B	Discussed various techniques involving pulse wave transmission. Reviewed the analytical and experimental work on this program performed by Dr. Attinger.
3.	Barnett, G.O.	Mass. Gen. Hospital, Boston, Mass.	L. Young	V	Discussed various noninvasive measurement possibilities, significance of venous pressure and tone measurements, and modeling of venous system.
4.	Brown, Ellen	Univ. of Calif. Med. Ctr. San Francisco, Calif.	D. Worthen	P	Interested in venous pressure relative to heart action. Has been recently concentrating on measurement of venous compliance and tone. Suggests venous occlusion plethysmography as a good technique.

* V - visit to, P - phone conversation, B - visited Biosystems

<u>No.</u>	<u>Individuals</u>	<u>Affiliation</u>	<u>Conducted By</u>	<u>Type of Contact*</u>	<u>Discussions & Results</u>
4.	Brown, Ellen (Continued)				Feels central venous pressure measurement is important to understanding of vascular dynamics. Suggested C. Hyman for capacitance plethysmography.
5.	Burch, G. E.	Tulane Med. Sch. New Orleans, La.	D. Worthen & S. Molner	P	Discussed his extensive work in digital plethysmography and in particular methods, techniques and hardware.
6.	Currier, R.	Space Labs, Inc. Van Nuys, Calif.	L. Stark & L. Young	V	Talked about the pulse wave velocity hardware developed for AFFTC (Edwards AFB) and described in FTCTR 66-7. Also discussed difficulties associated both with correlating pressure and pulse velocity and with utilizing a phonocardiogram in flight.
7.	Frazier, T.M. et al.	Lovelace Found. Albuquerque, N. Mexico	L. Young	V	This group favors the P-A delay technique. Suggested tests in which the transducers be implanted at the atria. Also suggested use of thermal flow meters for end-point detection.
8.	Fromer, P.	Nat. Heart Inst. Bethesda, Md.	L. Young	V	Discussed several noninvasive venous measurement techniques as well as the significance of venous pressure and tone measurements, especially in terms of cardiac function.

<u>No.</u>	<u>Individuals</u>	<u>Affiliation</u>	<u>Conducted By</u>	<u>Type of Contact*</u>	<u>Discussions & Results</u>
9.	Heckman, H.	Office of Surgeon Gen	L. Young	V	Reviewed the significance of

<u>No.</u>	<u>Individuals</u>	<u>Affiliation</u>	<u>Conducted By</u>	<u>Type of Contact</u> *	<u>Discussions & Results</u>
9.	Heckman, H.	Office of Surgeon Gen. Wash., D.C.	L. Young	V	Reviewed the significance of venous pressure and tone measurements, particularly with respect to shock and in surgery.
10.	Irwin, J.	Mass. Eye & Ear Infirmary Boston, Mass.	R. Brubaker	V	Felt that noninvasive techniques for venous pressure measurement are not yet practical.
11.	Mackay, I.F.S.	Univ. of Puerto Rico Med. Sch. San Juan, P. R.	R. Brubaker, D. Worthen, L. Young, J. Newman	P,B	Discussed Dr. Mackay's experience and thoughts relating to application of venous occlusion plethysmography, P-A delay, pulse wave velocity, A wave obliteration, pulse contour determination, measurement of cerebral blood flow and several other techniques. Dr. Mackay subsequently performed a number of experiments for us which greatly assisted us in evaluating several of the proposed techniques.
12.	Mount, J. et al.	IBM Res. Ctr. Houston, Tex.	L. Stark	V	Reviewed work done by this group in modeling and analysing the arterial pressure pulse and related phenomena.
13.	Reed, J.M.	Dept. of Phys. & Biophysics Univ. of Wash. Seattle, Wash.	L. Stark	V	Discussed various noninvasive venous measurement techniques including schemes for inferring vessel diameter, flow and pressure.

<u>No.</u>	<u>Individuals</u>	<u>Affiliation</u>	<u>Conducted By</u>	<u>Type of Contact*</u>	<u>Discussions & Results</u>
14.	Vogt, F.B.	Tex. Inst. & for Rehab. & Res. Houston, Texas.	L. Stark	V	Discussed various noninvasive techniques for monitoring venous system status. Reviewed the significance of venous pressure and distensibility measurements.
15.	Weltman, G.	Univ. of Calif. Los Angeles, Calif.	L. Young	V	Reviewed his work on arterial pulse wave velocity measurements, discussed the problems of pulse wave velocity measurements as applied to the venous system.