VASCULAR LABORATORY OPERATIONS MANUAL

A GUIDE TO SURVIVAL

REVISED SECOND EDITION

CLAUDIA BEAL RUMWELL, RN, RVT

VASCULAR LABORATORY OPERATIONS MANUAL

A GUIDE TO SURVIVAL

From laboratory finance, administration, and marketing to quality assurance, diagnostic procedures, and third-party billing, this manual offers proven step-by-step advice to anyone who is starting or already operating a vascular laboratory. The second edition of this widely used manual has been revised, updated, and expanded to include the most recent information about reimbursement, quality assurance, accreditation issues, and resources available to the vascular lab. Organized by the editor of the *Vascular Laboratory Policies & Procedures Manual* on LabDisk™ and written by thirty leading authorities on laboratory operations, the guide defines the role of the laboratory and its increasingly complex relationships to the community of referring physicians and institutions, third-party payors, government, and accrediting and credentialing organizations. It explains and itemizes every component of the facility and even includes sample floor plans. It offers dozens of proven ideas about how to promote laboratory services, with sample letters, charts, educational materials, and other resources that you can adapt for your own use. It gives you a system for documenting and analyzing test results, and it includes a practical guide to help you design and implement a quality assurance program tailored to your needs. It explains the new CPT codes and RVUs and offers tips on reimbursement. And it counsels the technologist about professional development, patient relations, and training. Coverage includes diagnostic equipment, general and financial management, computerization, contracts, laboratory procedures, and mobile testing. If the manual solves just one problem or results in one new referral, it more than pays for itself.

Other publications for the vascular laboratory:

Vascular Laboratory Policies & Procedures Manual, edited by Claudia Rumwell and Michalene McPharlin with D. E. Strandness and Edward Grant. Are you applying for ICAVL accreditation? *The* authorities on vascular procedures have written a P&P manual that comes on computer disk with user-friendly interactive software so that you can modify, update, and print it at will, saving you hundreds of hours of time. Endorsed and sponsored by SVT!

Introduction to Vascular Scanning: A Guide for the Complete Beginner, by Don Ridgway. An invaluable and truly unique guide for anyone who is learning or perfecting their scanning skills. The *Journal of Ultrasound in Medicine and Biology* calls this "an indispensable workbook for the novice, preceptor, and educator. It fills a major void in the literature [and] delivers what it promises. The reader will not be disappointed."

Vascular Technology: An Illustrated Review for the Registry Exam, by Claudia Rumwell and Michalene McPharlin. The first concise textbook-style review based on the Registry's own published outlines of exam content, this new work reviews and illustrates what you need to know to pass the Vascular Technology exam—topic by topic, in *one* volume, by leading technologists who themselves have taken, passed, and helped others prepare for and pass their RVT exams. Includes case examples and self-assessment quizzes.

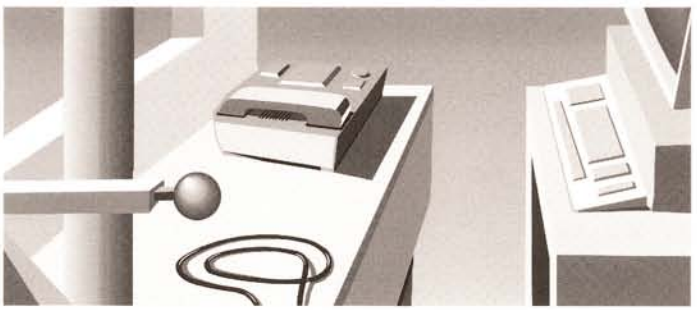
And: *The Vascular Laboratory: Current Issues and Clinical Developments* (Auer/Neumyer), *Techniques of Venous Imaging,* (Talbot/Oliver), *Techniques of Abdominal Vascular Sonography* (Neumyer/Thiele), *Vascular Anatomy and Physiology* (Belanger), *Vascular Technology Review* (Bean), *Vascular Physics Review* (Bean et al.), *Techniques of Peripheral Arterial Sonography* (Cato/Towne), *Techniques of Cerebrovascular Sonography* (Primozich/Strandness).

DAVIES PUBLISHING

ISBN 0-941022-24-2

VASCULAR LABORATORY OPERATIONS MANUAL

A GUIDE TO SURVIVAL



REVISED SECOND EDITION

CLAUDIA BEAL RUMWELL, RN, RVT

Consultant, Noninvasive Vascular Diagnostics
Portland, Oregon

DAVIES PUBLISHING

Publishers in Medicine and Surgery
Pasadena, California

Important Notice about Photocopying: This book is protected by a photo-alert system that makes unauthorized photocopying of returned materials apparent to the publisher. Unauthorized reproduction of any kind, including photocopying, is a violation of federal law and will be prosecuted.

Copyright © 1997 by Davies Publishing, Inc.
Publishers in Medicine and Surgery
32 South Raymond Avenue
Pasadena, California 91105-1935
818.792.3046 (telephone)
818.792.5308 (facsimile)
DAVIESCORP@aol.com (e-mail)

All rights reserved. No part of this work may be reproduced, stored in a retrieval system, or transmitted in any form or by any means, electronic or mechanical, including photocopying and recording, without permission in writing from the publisher.

Design and production by Graphics Two, Burbank, California

Library of Congress Cataloging-in-Publication Data

Vascular laboratory operations manual: a guide to survival / [edited by] Claudia Beal Rumwell.
— Rev. 2nd ed.
P. cm.
Includes bibliographical references.
ISBN O-941022-24-2
1. Blood-vessels—Diseases—Diagnosis. 2. Blood-vessels—Imaging. 3. Diagnosing, Noninvasive. 4. Medical laboratories—Management.
I. Rumwell, Claudia, 1946–
[DNLM: 1. Diagnosis, Laboratory—instrumentation—handbooks. 2. Diagnosis, Laboratory—methods—handbooks. 3. Laboratorles—organization & administration—handbooks. 4. Vascular Diseases—diagnosis—handbooks. WG 39 V331]
RC691.6.N65V37 1997
362.1'9613—DC20
DNLM/DLC
for Library of Congress 92-48990
CIP

ISBN 0-941022-24-2

CONTENTS

Section 1
The Vascular Laboratory

1.1 Introduction 1:**1**
1.2 History 1:**1**
1.3 The modern noninvasive vascular laboratory 1:**1**
1.3.1 Space 1:**1**
1.3.2 Equipment 1:**2**
1.3.3 Director 1:**2**
1.3.4 Technologists and technicians 1:**3**
1.3.5 Receptionist-secretary 1:**3**
1.3.6 Roles of personnel 1:**3**
1.4 Roles and benefits of the noninvasive vascular laboratory 1:**3**
1.4.1 Assessment of the carotid arteries 1:**4**
1.4.2 Arterial assessment of the extremities 1:**4**
1.4.3 Venous assessment of the extremities 1:**5**
1.4.4 Assessment of the abdominopelvic vasculature 1:**5**
1.5 Special uses of the noninvasive vascular laboratory 1:**5**
1.5.1 Measurement of pressures by transcutaneous cannulation 1:**5**
1.5.2 Ambulatory measurement of venous pressure 1:**6**
1.5.3 Intraoperative monitoring procedures 1:**6**
1.6 Conclusions 1:**6**

Section 2
The Laboratory Facility

2.1 Introduction 2:**1**
2.2 Interior design 2:**1**
2.3 Ambiance 2:**1**
2.4 Space 2:**2**
2.4.1 Size 2:**2**
2.4.2 Special architectural features 2:**4**
2.4.3 Scheduling area 2:**4**
2.4.4 The information center 2:**6**
2.4.4a Professional information 2:**6**
2.4.4b Educational materials 2:**6**
2.4.5 Administrative and secretarial space 2:**6**
2.4.6 Testing areas 2:**6**
2.4.7 Providing for patient privacy 2:**7**
2.4.8 Desk space for technologists and physicians 2:**7**
2.4.9 Storage facilities 2:**7**
2.4.10 Waiting/reception areas 2:**8**
2.4.11 Electrical power requirements 2:**8**
2.4.12 Heating and cooling 2:**8**
2.4.13 Washroom facilities 2:**8**
2.5 Communications 2:**8**
2.5.1 Equipment 2:**8**
2.5.2 The telephone as an image-maker 2:**9**
2.6 Diagnostic equipment and supplies 2:**9**
2.6.1 Testing equipment 2:**9**

2.6.2 Testing supplies 2:**9**
2.7 Office equipment and supplies 2:**10**
2.7.1 Office equipment 2:**10**
2.7.2 Waiting room furniture, fixtures, and supplies 2:**10**
2.7.3 Office supplies 2:**10**
2.8 Emergency considerations 2:**11**

Section 3
Diagnostic Equipment

3.1 Introduction 3:**1**
3.2 Preliminary research 3:**2**
3.2.1 Reviewing the literature 3:**2**
3.2.2 Attending seminars 3:**2**
3.2.3 Visiting noninvasive vascular laboratories 3:**2**
3.2.4 Evaluating manufacturers 3:**3**
3.3 Evaluating instruments 3:**3**
3.3.1 Cost 3:**4**
3.3.2 Ease of use 3:**5**
3.3.3 Speed of use 3:**5**
3.3.4 Quality of results 3:**6**
3.3.5 Accuracy of results 3:**6**
3.3.6 Portability 3:**6**
3.3.7 Equipment demonstrations 3:7
3.3.7a Setting up on-site demonstrations 3:**7**
3.3.7b Clinical user demonstrations 3:**7**
3.3.7c Evaluating new technology 3:**8**
3.4 Evaluating sales packages 3:**8**
3.4.1 Value 3:**9**
3.4.2 Price quotations and purchase agreements 3:**9**
3.5 Installation 3:**9**
3.6 Training 3:**10**
3.6.1 On-site training 3:**10**
3.6.2 Training seminars 3:**11**
3.7 Maintenance and service 3:**11**
3.7.1 Documenting maintenance and service 3:**11**
3.7.2 Warranties 3:**12**
3.7.3 Service contracts 3:**12**
3.7.4 Troubleshooting 3:**13**
3.8 System documentation 3:**13**

Section 4
General Management

4.1 Introduction 4:**1**
4.2 An overview of laboratory management 4:**2**
4.2.1 The technical director 4:**2**
4.2.1a Responsibilities in regard to equipment 4:**2**
4.2.1b Responsibilities in regard to research 4:**2**
4.2.1c Responsibilities in regard to clients 4:**3**
4.2.1d Maintaining technical expertise 4:**3**
4.2.2 The medical director 4:**3**
4.2.2a Responsibilities in regard to diagnostic tests 4:**3**
4.2.2b Responsibilities in regard to promotion 4:**3**
4.2.2c Support of the technical staff 4:**4**
4.2.3 The administrative director 4:**4**
4.2.3a Legal and financial responsibilities 4:**4**
4.2.3b Promotional and scheduling responsibilities 4:**4**
4.2.4 Working relationships 4:**5**
4.2.4a Communications within the laboratory 4:**5**
4.2.4b Communications with clients and the community 4:**5**
4.2.4c Maintaining good working relationships 4:**5**
4.3 Personnel 4:**5**
4.3.1 General considerations in hiring 4:**5**
4.3.2 The job description 4:**6**
4.3.3 The hiring process 4:**6**
4.3.3a Advertising and initial screening 4:**6**
4.3.3b The interview 4:**8**
4.3.3c Orientation of new employees 4:**8**
4.3.3d Probationary period 4:**8**
4.3.4 Performance reviews 4:**8**
4.3.5 Disciplinary procedures 4:**9**
4.3.5a Legal considerations 4:**9**
4.3.5b Guidelines for disciplinary actions 4:**10**
4.3.5c Grievance procedures 4:**11**
4.3.6 Wages and benefits 4:**11**
4.3.6a Wages 4:**11**
4.3.6b Benefits 4:**12**
4.3.7 Employee taxes 4:**13**
4.3.8 Employee records 4:**13**
4.4 Laboratory procedures 4:**13**
4.4.1 The procedures manual 4:**13**
4.5 The laboratory's library 4:**14**
4.5.1 Printed materials 4:**14**
4.5.1a Books 4:**15**
4.5.1b Journals 4:**15**
4.5.1c Reprints 4:**15**
4.5.1d Finding suitable reprints 4:**15**
4.5.2 Audiovisual materials 4:**16**
4.5.3 Organizing the catalogue file 4:**16**
4.5.4 Photographic slides 4:**16**
4.5.5 Case studies 4:**18**
4.6 Setting managerial goals 4:**18**

Section 5
Financial Management

5.1 Introduction 5:**1**
5.2 Start-up and expansion costs 5:**2**
5.2.1 Organizational costs 5:**2**
5.2.2 Leasehold improvements, furniture, and fixtures 5:**2**

5.2.3 Capital equipment 5:**3**
5.2.4 Office equipment and supplies 5:**4**
5.2.5 Financial aspects of staffing 5:**4**
5.3 Insurance 5:**5**
5.3.1 Malpractice insurance 5:**5**
5.3.2 General liability insurance 5:**5**
5.3.3 Business personal property insurance 5:**5**
5.4 Operations and cash flow 5:**6**
5.4.1 Methods of predicting cash flow 5:**6**
5.4.2 Cash flow in newly established facilities 5:**7**
5.4.3 Continuous modeling of cash flow 5:**8**
5.5 Accounting systems 5:**8**
5.5.1 Choosing the system 5:**8**
5.5.2 Financial controls and cash management 5:**9**
5.5.2a Monitoring incoming revenue 5:**9**
5.5.2b Monitoring outgoing revenue 5:**10**
5.5.3 Accounts receivable 5:**10**
5.5.3a The fee slip 5:**10**
5.5.3b Billing policies 5:**11**
5.5.3c Establishing a system for collections 5:**11**
5.5.4 Accounts payable 5:**12**
5.5.5 Payroll 5:**13**
5.5.5a Payroll period 5:**13**
5.5.5b Accounting for deductions 5:**13**
5.5.5c Overtime and benefits 5:**13**
5.6 Legal organization of the noninvasive vascular laboratory 5:**14**

Section 6
Daily Management

6.1 Introduction 6:**1**
6.2 Traffic 6:**2**
6.2.1 Scheduling and patient flow 6:**2**
6.2.2 Physician interpreters 6:**3**
6.2.3 Salespeople 6:**4**
6.2.4 Other visitors and events 6:**5**
6.2.5 Emergencies 6:**5**
6.3 Laboratory reporting 6:**6**
6.3.1 Preliminary reports 6:**7**
6.3.2 Contacts with physicians 6:**7**
6.3.3 Troubleshooting 6:**7**
6.4 Recordkeeping 6:**8**
6.4.1 Referring physicians 6:**8**
6.4.2 Patients per day and tests per day 6:**8**
6.4.3 Other records 6:**9**
6.5 Purchasing 6:**9**
6.5.1 Supplies 6:**9**
6.5.2 Equipment 6:**9**
6.5.3 Supplier card file 6:**9**
6.6 Accounts payable and receivable 6:**10**
6.7 Communications 6:**10**
6.7.1 Telephones 6:**10**
6.7.2 Mail 6:**10**

Section 7
The Computerized Laboratory

7.1 Introduction 7:**1**
7.2 Review of computer technology 7:**1**
7.2.1 Computer system definition 7:**2**
7.2.2 Programs are the intelligence of your computer 7:**2**
7.2.3 Hardware is tangible 7:**2**
7.3 Applications for vascular laboratories 7:**3**
7.3.1 Patient registry and laboratory data management 7:**3**
7.3.2 Laboratory interpretations and forms 7:**4**
7.3.3 Laboratory policies and procedures 7:**5**
7.3.4 Financial management 7:**6**
7.3.4a Storage and maintenance of patient accounts 7:**7**
7.3.4b Completion of insurance claim forms 7:**7**
7.3.5 Word processing 7:**7**
7.3.6 Marketing management 7:**7**
7.3.7 Spreadsheet 7:**8**
7.3.8 Database 7:**8**
7.3.9 Personal information manager 7:**9**
7.3.10 Communications 7:**9**
7.3.11 Network software 7:**9**
7.3.12 Scheduling or project management 7:**9**
7.3.13 Software prices 7:**9**
7.3.14 Custom programs 7:**9**
7.3.15 Software updates 7:**10**
7.3.16 Software performance 7:**10**
7.3.17 Consulting other users 7:**10**
7.3.18 RAM and disk storage requirements 7:**10**
7.4 Hardware 7:**10**
7.4.1 Computers (system units) 7:**11**
7.4.1a Speed 7:**11**
7.4.1b Reliability 7:**12**
7.4.1c Compatibility 7:**12**
7.4.1d Floppy disk drives 7:**12**
7.4.1e Hard disk drives 7:**13**
7.4.1f Backup devices 7:**13**
7.4.1g Monitors 7:**13**
7.4.1h Film recorders 7:**14**
7.4.1i Printers 7:**14**
7.5 Purchasing a new computer 7:**14**
7.6 The *Tao* of computer 7:**15**
7.7 Computer policies and procedures 7:**16**
7.7.1 System backup 7:**16**
7.7.1a Magnetic tapes 7:**16**
7.7.1b Tape log book 7:**16**
7.7.1c Standard tape backup operations 7:**16**

7.7.2 Software copyright and licensing 7:17
7.7.3 Protection against computer viruses 7:17

Section 8
Basic Strategies of Marketing and Promotion

8.1 Introduction 8:1
8.2 The marketing plan 8:1
8.2.1 Market analysis 8:2
8.2.1a Competing facilities 8:2
8.2.1b Competitive rate structures 8:2
8.2.1c Location 8:2
8.2.1d Timing of technological expansion 8:3
8.2.2 Marketing strategy 8:3
8.2.2a Setting performance goals 8:3
8.2.2b Establishing a pricing policy 8:4
8.3 Elements of a marketing program 8:4
8.3.1 Establishing the identity of the laboratory 8:4
8.3.1a The open house 8:4
8.3.1b Descriptive literature 8:5
8.3.1c Stationery and graphics 8:5
8.3.2 Advertising 8:6
8.3.3 Newsletters 8:6
8.3.4 Educational programs for referring physicians 8:6
8.3.5 Private meetings with referring physicians and staff 8:7
8.3.6 Patient education and community involvement 8:7
8.3.7 Standards and quality control programs as promotional tools 8:8
8.3.8 Public relations agencies 8:8
8.3.9 Analyzing and documenting marketing results 8:8
8.4 Innovative marketing ideas 8:9
8.4.1 Free testing 8:9
8.4.2 Follow-up programs 8:9
8.4.3 Rehabilitation and quality-of-life programs 8:9
8.4.4 Screening programs 8:9

Section 9
Strategies for Promoting the Vascular Laboratory

9.1 Introduction 9:1
9.2 Benefits of competition 9:1
9.3 Packaging the vascular laboratory: a plan for achieving recognition 9:3
9.3.1 Graphics 9:3
9.3.2 Test forms 9:3
9.3.3 The open house 9:4
9.3.4 The physicians' reference brochure 9:4
9.4 Promotional mailings 9:4
9.4.1 Targeting and timing mailings 9:4
9.4.2 Using the computer to systematize mailings 9:5
9.5 Advertisements 9:5
9.6 Using laboratory facilities for educational or community service purposes 9:5
9.7 Personal visits 9:6
9.8 Videotape presentations 9:6
9.8.1 Developing a master teaching tape 9:6
9.8.2 A sample format for a master teaching tape 9:6
9.8.3 Using videotapes at exhibits and meetings 9:7
9.9 The promotional notebook 9:7
9.10 Continuing education presentations 9:7
9.11 Additional marketing tools 9:8
9.12 The marketing master-file notebook 9:8
9.12.1 Things to do 9:8
9.12.2 Monthly subdivisions 9:8
9.12.3 Meetings section 9:8
9.12.4 Goals section 9:8
9.12.5 Promotional ideas 9:8
9.12.6 Potential referring physicians 9:9
9.12.7 Alphabetized sections 9:9
9.12.8 Public relations tools 9:9
9.12.9 Journal articles used for marketing 9:9
9.12.10 Lists of incoming interns and residents 9:9
9.12.11 Continuing education presentations 9:9
9.12.12 Miscellaneous sections 9:9
9.13 Conclusions 9:9

Section 10
Contracts

10.1 Introduction 10:1
10.2 Research 10:1
10.3 Contracts 10:1
10.4 The proposal 10:2
10.5 The contract 10:3
10.5.1 Contract outline 10:4
10.5.2 Sample contracts 10:4
10.5.3 Miscellaneous provisions 10:6

Section 11
Reimbursement

11.1 Introduction 11:1
11.2 Basic aspects of Medicare regulations 11:2
11.2.1 Background and administration of Medicare 11:2
11.2.2 "Participating" versus "nonparticipating" providers 11:2
11.2.3 Coding for noninvasive procedures 11:2

11.2.4 Establishing a smooth working relationship with the Medicare carrier 11:**3**
11.3 Guidelines for relationships with third-party payors 11:**4**
11.3.1 Establishing new relationships 11:**4**
11.3.2 Using a tickler file 11:**5**
11.3.3 Making the initial contact 11:**5**
11.3.3a Establishing identity 11:**6**
11.3.3b Requesting information from the carriers 11:**8**
11.3.3c Arranging face-to-face meetings 11:**8**
11.3.4 Working relationships and problem solving 11:**8**
11.4 Regulations regarding billing procedures 11:**9**
11.4.1 Diagnostic Related Groups (DRGs) 11:**9**
11.4.2 Current Procedural Terminology (CPT) codes 11:**10**
11.4.3 Diagnosis codes 11:**12**
11.5 Determining charges 11:**12**
11.6 Accounting related to third-party claims 11:**12**
11.7 Additional considerations 11:**14**
11.8 Current reimbursement issues and developments 11:**15**
11.8.1 CPT codes 11:**15**
11.8.2 HCFA fee schedule and RVUs 11:**16**
11.8.3 Independent physiological laboratories (IPLs), low-cost ultrasound equipment, pocket Dopplers, and zero crossers 11:**17**
11.8.3a IPLs 11:**17**
11.8.3b Low-cost ultrasound equipment 11:**18**
11.8.3c Pocket Dopplers: Management Advisory Report 11:**18**
11.8.3d Zero Crossers 11:**19**
11.8.4 The appeals process: practical advice about the politics and mechanics of reimbursement 11:**19**
11.8.4a Claim form submission 11:**19**
11.8.4b Medical necessity 11:**19**
11.8.4c The appeals process—initial review 11:**19**
11.8.4d Request a Fair Hearing (Review) 11:**20**
11.8.4e The Fair Hearing Officer 11:**20**
11.8.4f Fair Hearing options 11:**20**
11.8.4g Your rights during a Fair Hearing 11:**20**
11.8.4h Hearing by an Administrative Law Judge (ALJ) 11:**20**
11.8.4i Appeals Council Review (ACR) 11:**20**
11.8.4j Judicial recourse 11:**20**
11.8.4k Be prepared 11:**20**
11.8.5 Useful names and numbers 11:**20**
11.8.5a Names, addresses, and telephone numbers of Medical Part B carriers 11:**21**
11.8.5b Regional office contacts 11:**26**
11.8.5c Miscellaneous names, numbers, and other data 11:**26**
11.8.6 References 11:**26**

Section 12
The Vascular Technologist

12.1 Introduction 12:**1**
12.2 Technologist versus technician 12:**1**
12.3 Education, training, and credentialing 12:**3**
12.3.1 Education 12:**3**
12.3.2 Training 12:**4**
12.3.3 Credentialing 12:**5**
12.4 Laboratory skills and responsibilities 12:**7**
12.4.1 Skills and responsibilities related to medical diagnosis 12:**7**
12.4.1a The venous system 12:**7**
12.4.1b The arterial system 12:**8**
12.4.1c Diagnostic responsibilities 12:**8**
12.4.2 Technical skills and responsibilities 12:**8**
12.4.3 Administrative skills and responsibilities 12:**9**
12.4.4 Interpersonal skills 12:**10**
12.5 Standards and quality control 12:**10**
12.5.1 Standards 12:**10**
12.5.2 Quality control 12:**10**
12.5.3 Test accuracy 12:**11**
12.5.4 Quality control of administrative function 12:**11**
12.5.5 Patient safety 12:**11**
12.6 Professional development 12:**12**
12.6.1 Professional organizations 12:**12**
12.6.2 Continuing education 12:**13**
12.6.3 Networking 12:**13**
12.7 Hiring a technologist 12:**14**
12.7.1 Locating appropriate candidates 12:**14**
12.7.2 Evaluating candidates 12:**14**
12.8 Developing and documenting policies 12:**14**
12.9 Conclusions 12:**15**

Section 13
Laboratory Procedures

13.1 Introduction 13:**1**
13.1.1 Principles of Doppler ultrasound 13:**1**
13.1.2 Limitations and special techniques 13:**2**
13.2 Tests of the extracranial cerebrovascular system 13:**2**
13.3 Indirect tests of the extracranial cerebrovasculature 13:**2**
13.3.1 Ocular pneumoplethysmography (OPG-Gee) 13:**2**
13.3.2 Periorbital Doppler evaluation 13:**3**

13.4 Direct tests 13:3
13.4.1 Duplex ultrasonography and color flow imaging 13:3
13.4.2 Transcranial Doppler ultrasound 13:4
13.5 Testing of the peripheral arterial system 13:4
13.5.1 Doppler evaluation of the lower extremities 13:4
13.5.1a Procedure 13:5
13.5.1b Treadmill stress testing 13:5
13.5.2 Doppler evaluation of the upper extremities 13:6
13.5.3 Photoplethysmography (upper or lower extremities) 13:6
13.5.4 Segmental pulse volume plethysmography (upper or lower extremities) 13:6
13.5.5 Strain gauge plethysmography (upper or lower extremities) 13:6
13.5.6 Duplex ultrasonography of the lower extremities with or without color flow imaging 13:7
13.5.7 Miscellaneous limitations of arterial evaluation of the extremities 13:7
13.5.8 Impotency testing 13:7
13.6 The venous system 13:8
13.6.1 Impedance plethysmography (upper and lower extremities) 13:8
13.6.2 Venous occlusion plethysmography 13:8
13.6.3 Strain gauge plethysmography 13:9
13.6.4 Air plethysmography (APG) 13:9
13.6.5 Limitations of plethysmography 13:9
13.6.6 Phleborheography (PRG) 13:9
13.6.7 Venous Doppler evaluation 13:10
13.6.7a Points of evaluation 13:10
13.6.7b Limitations of the deep venous Doppler technique 13:10
13.6.8 Duplex imaging of the veins of the extremities 13:11
13.6.8a Points of evaluation 13:11
13.6.8b Limitations of the B-mode/pulsed Doppler technique 13:11
13.7 Evaluation of the abdominal vasculature 13:11
13.7.1 Procedures for evaluation of the abdominal vasculature 13:12
13.7.2 Limitations of abdominal imaging techniques 13:12

Section 14
Quality Improvement and QA Statistics

14.1 Introduction 14:1
14.1.1 Adequate space 14:1
14.1.2 Appropriate equipment 14:1
14.1.3 Qualified personnel 14:1
14.1.4 Testing procedures 14:2
14.1.5 Indications for testing 14:2
14.1.6 Obtaining data for comparison 14:2
14.1.7 Statistical correlation 14:2
14.2 Implementing a quality assurance program 14:3
14.2.1 Step 1: Assign responsibility (Who is responsible?) 14:3
14.2.2 Step 2: Define the scope of care (What do we do?) 14:4
14.2.3 Step 3: Identify important aspects of care (What is most important?) 14:4
14.2.4 Step 4: Establish quality monitors or indicators (What should we look at?) 14:4
14.2.5 Step 5: Establish thresholds (What's considered "good?") 14:7
14.2.6 Step 6: Collect data (Get the facts!) 14:7
14.2.7 Step 7: Evaluate performance/care provided (How are we doing?) 14:9
14.2.8 Step 8: Solve identified problems (Are changes needed?) 14:9
14.2.9 Step 9: Assess effect of the change (Are things better?) 14:10
14.2.10 Step 10: Communicate findings (Does anybody know?) 14:10
14.2.11 FOCUS-PDCA 14:10
14.3 QA statistics 14:11
14.3.1 Sensitivity 14:11
14.3.2 Specificity 14:11
14.3.3 Positive predictive value 14:11
14.3.4 Negative predictive value 14:11
14.3.5 Accuracy 14:12
14.3.6 Comparing noninvasive and gold standard results 14:12
14.3.7 Obtaining reports for comparison 14:13
14.4 Conclusion 14:14

Section 15
Mobile Vascular Testing

15.1 Introduction 15:1
15.2 Physical facilities of the mobile laboratory 15:1
15.2.1 Office facilities 15:1
15.2.2 Vehicles 15:1
15.3 Staffing the mobile laboratory 15:2
15.3.1 Technologists 15:2
15.3.2 Clerical staff 15:2
15.3.3 Management 15:2
15.4 Diagnostic equipment for mobile vascular testing 15:2
15.4.1 Selecting equipment 15:2
15.4.2 Duplication 15:3
15.4.3 Supplies 15:3
15.5 Insurance 15:3

15.5.1 Vehicular insurance 15:3
15.5.2 Equipment insurance 15:3
15.5.3 Professional insurance 15:3
15.6 Maintenance and service contracts for mobile equipment 15:3
15.6.1 Vehicular maintenance 15:4
15.6.2 Diagnostic equipment 15:4
15.7 Scheduling of mobile testing 15:4
15.7.1 Routine scheduling 15:4
15.7.2 Availability 15:4
15.8 Reports of mobile laboratory testing 15:4
15.8.1 Preliminary reports 15:4
15.8.2 Final reports 15:5
15.9 Marketing and promotion 15:5
15.9.1 Marketing to physicians and their staffs 15:5
15.9.2 Marketing to hospitals 15:5
15.10 Testing locations 15:5
15.10.1 Loading and unloading at the testing locations 15:5
15.10.2 Parking 15:5
15.11 Billing for mobile laboratory testing services 15:5

Section 16
Resources

16.1 Introduction 16:1
16.2 Publications 16:1
16.2.1 Books 16:2
16.2.2 Journals 16:3
16.2.3 Audiotapes 16:4
16.2.4 Videotapes 16:4
16.2.5 Registry reviews 16:4
16.2.6 Software 16:5
16.2.7 Laboratory accreditation materials 16:5
16.2.8 Publishers 16:5
16.2.9 Other educational resources 16:6
16.3 Patient education 16:6
16.4 Professional organizations 16:7
16.5 Training centers 16:8
16.6 Equipment manufacturers and suppliers 16:9
16.7 Sample promotional letters, laboratory forms, and other marketing devices 16:11

Section 17
Addenda

Section 18
Slide Graphics for the Vascular Lab

18.1 Purpose 18:1
18.2 Who should use slide graphics 18:1
18.3 How to use slide graphics 18:2
18.4 How to modify slides or add your own slides to the set 18:2
18.5 Contents and Presentation Notes 18:3

1

THE VASCULAR LABORATORY

1.1 Introduction The noninvasive vascular laboratory provides a service to clinicians who are treating vascular diseases. The information that the vascular laboratory generates complements a) the clinical impression derived from the history and physical examination and b) information obtained from angiography, an invasive diagnostic procedure. A noninvasive vascular laboratory consists of personnel, facilities, and instrumentation dedicated to a single goal: enhancing the assessment of patients who have, or are at risk for, vascular disorders.

1.2 History In terms of basic science, the noninvasive vascular laboratory traces its roots to physiology, the science that defines the normal function of the body. Clinically, until the early 1950s, physicians for the most part were limited merely to diagnosing most vascular diseases. The patient's history and the physical examination were the principal diagnostic tools. At that time angiography had been available for more than two decades, but it was used primarily to enhance diagnostic accuracy. Once vascular disease was diagnosed, there was little hope of altering its course by any form of intervention.

Although physiologists could evaluate hemodynamics noninvasively with the hydraulic plethysmograph, use of this cumbersome device was necessarily restricted to clinical research applications. The development of a volume-calibrated digital and segmental pneumatic plethysmograph made clinical application of noninvasive techniques feasible. Winsor, who was the first to report extensive clinical application of this instrument,[1] is widely acknowledged as the pioneer in this area. Other techniques followed, including strain gauge, photoelectric, impedance/capacitance, and pneumatic plethysmography, as well as ultrasound in its many aspects. To list the many researchers and clinicians who contributed to the development and application of these techniques is beyond the scope of this text. To learn the detailed history of noninvasive vascular technology and to appreciate its international background, the reader is encouraged to consult outside sources.

1.3 The modern noninvasive vascular laboratory The facilities and equipment required for a noninvasive vascular laboratory are discussed in detail in sections 2 and 3. Some general observations are presented here.

1.3.1 Space Space requirements vary according to test volume and the base of operation. For an independent laboratory in an office setting, administrative requirements are usually met

within the facility. If the laboratory is located in a hospital, and if the test volume so warrants, a more elaborate administrative infrastructure is needed.

For an institutionally based noninvasive vascular laboratory, the ideal location would be in a cluster consisting of the noninvasive cardiac laboratory, the neurodiagnostic laboratory, the nuclear medicine department, and the angiography suite of the radiology department. The author's institution closely approximates this ideal: All except the angiography suite are clustered, but the radiology department is one floor removed from this cluster. Under these circumstances the noninvasive vascular laboratory, rather than the radiology department, is responsible for correlating the laboratory's findings with those of the angiography suite.

1.3.2 Equipment The subject of equipment is addressed in detail in section 3, but some general observations are pertinent here. Like all areas of medicine, the noninvasive vascular laboratory has experienced a technological explosion over the past decade. These advances represent major accomplishments, but perspective must be maintained. Some examples in which the noninvasive vascular laboratory is not routinely involved serve to illustrate this point. Sophisticated electronic instruments are now available for clinical temperature measurements. Under appropriate circumstances, these devices have replaced the standard clinical thermometer. However, the electronic thermometer can deviate from normal function, and its maintenance is an important factor in its use. The simplicity of the standard clinical thermometer will ensure its continued use in many circumstances. Similarly, the blood pressure cuff and stethoscope, in the hands of an appropriately trained individual, remain the standard against which electronic instruments are measured. The simplicity, reproducibility, and universality of the blood pressure cuff and stethoscope warrant their continued application.

In the realm of vascular diagnostic techniques, the single most significant advance has been the basic unidirectional Doppler ultrasound velocity detector. Used in conjunction with multisegment extremity placement of the blood pressure cuff, the Doppler device permits accurate measurement of systolic pressure in distal segments of the extremities. The ability to detect systolic pressure gradients in the extremities with this uncomplicated instrumentation remains an important element of noninvasive vascular diagnostic practice. This technique is likely to remain in the noninvasive vascular laboratory's armamentarium for a long time.

Remarkable sophistication of ultrasound diagnosis has been achieved with the development of high-resolution imaging and spectral analysis. More recently, advances have been made in portraying blood flow in color through the technique of color flow imaging, simultaneous real-time imaging that portrays blood flow in color and tissue in gray scale. These instruments are costly, and considerable skill is required of the technologist if useful results are to be obtained. Nevertheless, these technologies must be considered an essential of the noninvasive vascular laboratory. The principal application of high-resolution imaging and spectral analysis has been in detecting atherosclerosis of the carotid arteries and deep venous thrombosis in the extremities. More recently, increasing attention has been directed at investigation of the abdominopelvic vasculature as well as the arterial vasculature of the lower extremities. Because this area of diagnosis has advanced in the expected manner, it is difficult to see how any noninvasive vascular laboratory could avoid introducing sophisticated technologies of this type.

1.3.3 Director In some cases a noninvasive vascular laboratory has a volume of testing sufficient to require a full-time director, but in many other cases this is not necessary. Most clinical noninvasive vascular laboratories are directed by physicians, although doctoral-level scientists with the required clinical expertise may also serve in this capacity. Physicians representing a wide variety of specialties have become involved in directing noninvasive vascular laboratories. Whatever the director's specialty area, the role demands genuine interest and, for the immediate future, a willingness to obtain training beyond the usual residency or fellowship (refer to section 4.2.2).

It has been suggested that some noninvasive vascular technologists have a greater appreciation than most physicians and laboratory directors of the vagaries and subjective aspects of vascular testing and its interpretation.[2] This opinion may be overstated, but it contains an

element of truth. Its most serious implication lies in the fact that some technologists have assumed responsibility for the selection of instruments acquired, tests performed, and reports generated by the laboratories with which they are associated. The medical, legal, and ethical aspects of this responsibility may not be fully appreciated by these technologists, who are cautioned that a physician, clinical scientist, or institution that allows the technologist to assume total or near-total responsibility may be reluctant to share in the consequences of any misadventure.

1.3.4 Technologists and technicians Noninvasive vascular technologists and noninvasive vascular technicians have distinct areas of responsibility and expertise. The differences between the two can be readily appreciated in three areas: assessment of patients before testing, performance of tests, and post-test management of the information obtained. This topic is discussed in section 12.2; here, it suffices to say that no confusion should exist concerning the technologist/technician distinction.

1.3.5 Receptionist-secretary A receptionist-secretary is likely to be required only by the high-volume, hospital-based noninvasive vascular laboratory. Such time-consuming tasks as scheduling, reporting, and correspondence can be more economically performed by nontechnical personnel if the test volume warrants hiring them. The secretary-receptionist should work under the immediate direction and instruction of the chief technologist.

1.3.6 Roles of personnel A major role of the laboratory director is maintaining staff morale. This statement, which has broad implications, may surprise some readers. However, two studies cite the frustrations and discouragements of technologists in situations where laboratory directors have been unwilling or unable to assume this vital function.[2,3] These same two sources suggest that personality clashes are a major factor in problems of morale. Unfortunately, they offer no solution. The key to harmony is mutual respect. If a technologist perceives a director as being informed about the technical demands of noninvasive vascular testing, it follows that the technologist may feel that the director appreciates highly skilled technical performance. In other words, the director is perceived as having respect for the technologist's contribution to the quality of the laboratory's work.

The converse is true as well, in which case a simple solution is for the director to assume the role of the technologist temporarily whenever a new instrument or test is introduced. In this way the director may begin to comprehend the problems encountered and the alternatives required to overcome them. By personally confronting the problems of the technologist, the director can offer *constructive* criticism of the technologist's performance.

The director of the noninvasive vascular laboratory also can improve staff morale by preventing abuse of laboratory personnel by clients. Most people respond willingly to genuine emergencies and urgencies. Unfortunately, immature individuals may exploit this propensity to help by demanding immediate service even when no emergency or urgency exists. The laboratory director must assume responsibility for a reasonable policy in this regard. Personnel are more likely to respond to clinician requests with good service if the director has ensured that they will not be abused by clinicians or their representatives.

1.4 Roles and benefits of the noninvasive vascular laboratory Refining our definition of the noninvasive vascular laboratory, we find that its role is to assist physicians in making clinical diagnoses regarding circulatory conditions by assessing the hemodynamic function and the anatomic features of the arterial and venous systems. Through its findings, the laboratory assists in determining the need for more complex, more extensive, and often invasive procedures.

The varied benefits offered by the noninvasive vascular laboratory include the following:

- Determining and documenting the presence, location, and severity of vascular disease.
- Providing quantitative comparative data for evaluating the stability, progression, or regression of the disease.
- Yielding physiologic information that augments the anatomic information provided by invasive procedures.
- Determining patients in whom findings are negative, thereby avoiding unnecessary arteriography or venography while reducing the cost and risk to the patient.

Traditionally, noninvasive vascular tests have been categorized as belonging to one of three groups. The first group of tests includes those directed at assessment of the carotid arteries. The second group is composed of tests used to evaluate the arteries of the extremities. The third group encompasses tests of the venous system of the extremities, primarily those of the legs and feet. More recently, ultrasound technologies have been used in evaluating the visceral and retroperitoneal abdominopelvic vasculature (see section 13). Direct measurement of arterial, venous, and tissue pressures is included among the services of many noninvasive vascular laboratories, although these technologies may be strictly defined as invasive.

Numerous books on noninvasive vascular diagnosis describe every conceivable test applicable in various situations, discussion of which is beyond the scope and intention of this chapter.[3,4] Nevertheless, the philosophy of testing as it is practiced in the noninvasive vascular laboratory of a large community hospital may be helpful to the reader.

1.4.1 Assessment of the carotid arteries At one community hospital, more than 1000 coronary bypasses and 350 coronary arterioplasties were performed in a recent year. Even assuming that none of these patients had any signs or symptoms of carotid disease, the risk of a stroke in association with either of these procedures cannot be ruled out. Low perfusion pressures (60–80 mm Hg) are commonly observed during coronary bypass procedures, and hypotension has been observed during coronary arterioplasties. If the patient has a carotid lesion of hemodynamic consequence, the risk of stroke during either procedure is increased. Although there is controversy regarding the desirability of repairing asymptomatic carotid lesions either prior to or in conjunction with coronary bypass procedures, there is no disputing the need to be aware of the existence of such lesions, especially since this information affects informed consent. Carotid duplex interrogation and/or ocular pneumoplethysmography can be used to detect significant disease in these patients. In our laboratory, patients who present with either local or global symptoms that suggest carotid disease are initially evaluated with both ocular pneumoplethysmography and carotid duplex ultrasound. The findings of either or both may dictate urgent or emergent arteriography and suggest which of the available arteriographic techniques are appropriate. The preoperative noninvasive tests also serve as a baseline to which postoperative testing can be compared.[5,6] (See sections 13.3 and 13.4 for details about direct and indirect tests.)

1.4.2 Arterial assessment of the extremities The single most useful test offered by the noninvasive vascular laboratory remains accurate measurement of systolic pressures at multiple levels in the extremities using a bidirectional Doppler velocity detector and a standard blood pressure cuff. The test is simple and economical. It demonstrates arterial lesions of hemodynamic consequence by detecting systolic pressure gradients within one extremity or between extremities. This technique is somewhat enhanced by an analysis of arterial wave character as detected with strain gauge, impedance, or pneumatic volume plethysmography.

Although duplex ultrasound imaging and spectral analysis have been used primarily for carotid assessment, this technique is currently being applied to the evaluation of arterial disease of the extremities. One laboratory found it to be particularly useful in evaluating the status of superficially located prosthetic arterial bypasses, especially those of the axilloaxillary and axillofemoral type. Others consistently use it to follow all types of arterial bypass grafts, in addition to localizing disease in the native arteries after a physiologic test (e.g., Doppler segmental blood pressures and velocity waveform analysis) indicates an obstruction and evaluating (pre- and post-) angioplasty procedures. This technology also is used to evaluate hemodialysis access grafts.

One problem has defied many attempts at solution: the assessment of the severely ischemic extremity to locate the most distal site at which an amputation would heal. The ideal test would identify the maximum distance at which virtually all amputations would heal, while minimizing the risk that poor healing would necessitate revision of the amputation. At present, a most promising technique appears to be the transcutaneous measurement of the tissue pressures of carbon dioxide and oxygen together with the ratios of these observations.

1.4.3 Venous assessment of the extremities Until the 1980s, the combination of continuous-wave Doppler and plethysmography was the mainstay of venous testing in most laboratories.

The Doppler technique consisted of listening for phasic venous flow signals and then using distal calf compression to augment flow. This test was accurate for identifying obstructive thrombi in the proximal veins but was not sensitive to nonobstructive thrombi or isolated calf vein thrombi. This test was also very subjective and required a great deal of skill. The plethysmographic tests (mainly impedance plethysmography and phleborheography) were, like the Doppler examinations, accurate for detecting major obstructive thrombi above the knee but not sensitive to nonobstructive thrombi. Therefore, some of the most dangerous thrombi—those that were poorly attached to the vein wall—were going undetected. In the early 1980s the application of real-time B-mode imaging to the venous system evolved and eventually allowed direct visualization of the entire venous circuit. This venous imaging test involves the application of probe pressure to demonstrate the presence or absence of thrombus. When present, thrombus is imaged as echogenic material within the lumen of the vein. Using this technique, the vascular laboratory can visualize even small nonobstructive thrombi that would otherwise go undetected by Doppler or plethysmographic examination alone.

For a while, duplex ultrasonography was simply added to the conventional Doppler and plethysmographic examinations. Once they mastered venous imaging techniques, most laboratories eventually discontinued plethysmographic studies as redundant. The Doppler component has been retained, however, with most laboratories now using pulsed- rather than continuous-wave Doppler. Because the veins being listened to can be directly imaged with pulsed-Doppler ultrasound, the learning curve for venous Doppler examinations has been shortened dramatically. The addition of color flow technology further enhances the duplex evaluation.

Venous imaging by duplex ultrasonography (with or without color flow imaging) has now become the standard technique for detecting or ruling out venous thrombosis in the vascular laboratory. Nevertheless, in some institutions where there is no access to expensive duplex ultrasound equipment, plethysmography and continuous-wave Doppler examinations are still in use. It is important for these and any other laboratories planning for accreditation to consult the most current *Essentials and Standards* published by the Intersocietal Commission for the Accreditation of Vascular Laboratories. The ICAVL considers duplex ultrasonography to be the only primary noninvasive diagnostic modality for the assessment of venous disease.

1.4.4 Assessment of the abdominopelvic vasculature In many institutions, the radiology department has had extensive experience with a variety of abdominopelvic ultrasound tests. At the author's institution, the radiology department has been a primary source for nondynamic aortic imaging. It appears that duplex ultrasound testing of the retroperitoneal vasculature has become more common as the techniques become more sophisticated and as quality assurance follow-up has helped to define interpretation parameters. This might be an area in which the radiology department and the noninvasive vascular laboratory could establish a joint effort.

1.5 Special uses of the noninvasive vascular laboratory A number of services provided by the noninvasive vascular laboratory may be classified as special. In some instances, these services involve interdisciplinary cooperation.

1.5.1 Measurement of pressures by transcutaneous cannulation A rigid interpretation of the role of the noninvasive vascular laboratory requires that all tests be strictly noninvasive. Under such an interpretation, transcutaneous cannulation of arteries, veins, and tissue compartments to obtain pressure measurements would be considered invasive. Nevertheless, it is minimally so, and the noninvasive vascular laboratory should be prepared to provide these measurements. Some laboratories provide arterial pressure monitoring in the radiology department to complement such procedures as arteriography and balloon arterioplasty. Documentation of iliac-segment arterial pressure gradients is important to the planning of lower-extremity arterial reconstructions. Similarly, an essential element of good medical practice in balloon arterioplasty is preprocedure documentation of the pressure gradient across the stenotic lesion combined with

postprocedure determination that this gradient has been reduced or eliminated.

1.5.2 Ambulatory measurement of venous pressure Measurements of venous pressure in patients with deep venous obstruction or valvular incompetence has assumed an important role in determining the necessity for operative intervention. Although these measurements may comprise a very small proportion of the service provided by a noninvasive vascular laboratory, haphazard performance of these determinations can be seriously misleading. A dual-channel pressure-monitoring system that provides pressure-calibrated tracings is desirable for all arterial and venous pressure determinations. The tracings should become part of the patient's records.

1.5.3 Intraoperative monitoring procedures If pressure-calibrated tracings are to be obtained throughout a surgical procedure, a cooperative effort is required. During carotid reconstruction, the anesthesiologist may join with the surgeon to provide a series of arterial pressure measurements. The anesthesiologist institutes a cannulation of the radial artery. During the operation, the anesthesiologist provides the surgeon with an additional pressure line for direct measurements of carotid pressure. This pressure line may be connected to a separate transducer and monitoring channel, or it may be connected to the radial artery pressure line and transducer by means of a three-way stopcock. To measure carotid pressure, the external carotid artery is occluded with a clamp, and two pressure determinations are made. The initial determination is made with the needle inserted into a distal segment of the common carotid artery that is relatively free of atherosclerosis. The common carotid artery is not occluded for this measurement. A second pressure is obtained with clamp occlusion of the proximal common carotid artery.

Some clinicians use the data obtained in this manner primarily to determine whether an indwelling arterial shunt is to be used during the carotid repair. However, the information is more important for its predictive value in assessing the tolerance of the respective cerebral hemisphere to total carotid occlusion in the event of postoperative thrombosis or subsequent early fibroproliferative recurrence of stenosis. Although generated with equipment provided and operated by the anesthesiology department, these permanent pressure-calibrated records are entered into the patient records maintained by the noninvasive vascular laboratory. Here again is a situation where cordial cooperation between the noninvasive vascular laboratory and other institutional departments yields dividends for all concerned, but most especially for the patient.

1.6 Conclusions The focus of a noninvasive vascular laboratory is service to the clinician (and thereby to the patient). This service must be prompt and efficient, but above all it must be of high quality. Quality assurance does not reside solely in the director, nor should it; it is the responsibility of every member of the staff. High quality can be initiated and maintained only by continuing review and correlation of technological performance and test interpretation with information generated elsewhere: angiography, operative findings, and clinical outcomes. See section 14.

Clinicians are acutely aware of anecdotal instances in which the noninvasive vascular laboratory has been wrong. Such isolated impressions can be effectively countered only by honest acknowledgment of any errors that occur and regular promulgation of overall results. The preparation of papers for publication in peer-reviewed journals is an ideal method of announcing results. Presentation of the same material at institutional conferences is a highly acceptable alternative. One should always avoid the unscientific practices of championing causes (other than the advancement of knowledge) and berating those with opposing views. Similarly, the activities of instrument manufacturers in relation to technologists must be carefully circumscribed. To the credit of most commercial endeavors, their efforts have been strongly supportive without being intrusive.

More than a century ago, on May 3, 1883, Sir William Thomson (Lord Kelvin) began a lecture at the Institution of Civil Engineers with these words:

> In physical science a first essential step in the direction of learning any subject is to find principles of numerical reckoning and practicable methods for measuring some quality connected with it. I often say that when you

> can measure what you are speaking about and express it in numbers you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind: it may be the beginning of knowledge, but you have scarcely, in your thoughts, advanced to the stage of *science*, whatever the matter may be. . . .[7]

Unfortunately, when biologic science is coupled with physical science, the numbers must frequently be expressed with large standard deviations. In this regard, the author will now make an exception to the decision to omit any litany of names associated with the history of noninvasive vascular diagnostic techniques. The development and maturation of duplex ultrasound has included the efforts of many, but two names stand out among those pursuing the science of this discipline. These same two individuals have been associated with the development and mathematical definition of a wide variety of noninvasive vascular instrumentation. The reader would do well to include the textbook by D. Eugene Strandness and David S. Sumner among the classic references.[8]

References

1. Winsor T: Influence of arterial disease on the systolic blood pressure gradients of the extremity. Am J Med Sci 220:117–126, 1950.
2. Bean BA: The vascular laboratory technologist. In Kempczinski RF, Yao JST (eds): *Practical Noninvasive Vascular Diagnosis,* 2nd ed. Chicago, Year Book Medical Publishers, 1987, pp 16–21.
3. Kupper CA, Nix ML: Organization of the vascular laboratory: practical considerations. In Bernstein EF (ed): *Noninvasive Diagnostic Techniques in Vascular Disease,* 3rd ed. St. Louis, CV Mosby, 1985, pp 855–860.
4. Kempczinski RF: Vascular diagnostic laboratory: organization and operation. In Kempczinski RF, Yao JST (eds): *Practical Noninvasive Vascular Diagnosis,* 2nd ed. Chicago, Year Book Medical Publishers, 1987, pp 2–15.
5. The editors: Controversies in the noninvasive evaluation of extracranial arterial disease. In Bernstein EF (ed): *Noninvasive Diagnostic Techniques in Vascular Disease,* 3rd ed. St. Louis, CV Mosby, 1985, p 490.
6. Kempczinski RF: Indirect cerebrovascular testing. In Kempczinski RF, Yao JST (eds): *Practical Noninvasive Vascular Diagnosis,* 2nd ed. Chicago, Year Book Medical Publishers, 1987, pp 262–285.
7. Thomson W: *Popular Lectures and Addresses,* vol I, 2nd ed. New York, Macmillan, 1891, pp 80–81.
8. Strandness DE, Sumner DS: *Hemodynamics for Surgeons.* New York, Grune & Stratton, 1975.

Suggested Readings

Auer AI, Neumyer MN (eds): *The Vascular Laboratory: Current Issues and Clinical Developments.* Pasadena, CA, Davies Publishing (in press, 1997).

Bernstein, EF (ed): *Noninvasive Diagnostic Techniques in Vascular Disease,* fourth edition. St. Louis, Mosby-Year Book, 1994.

Zwiebel WJ (ed): *Introduction to Vascular Ultrasonography,* third edition. Philadelphia, Saunders, 1992.