Endarterectomy for Asymptomatic Carotid Artery Stenosis

Executive Committee for the Asymptomatic Carotid Atherosclerosis Study

Objective.—To determine whether the addition of carotid endarterectomy to aggressive medical management can reduce the incidence of cerebral infarction in patients with asymptomatic carotid artery stenosis.

Design.—Prospective, randomized, multicenter trial.

Setting.—Thirty-nine clinical sites across the United States and Canada.

Patients.—Between December 1987 and December 1993, a total of 1662 patients with asymptomatic carotid artery stenosis of 60% or greater reduction in diameter were randomized; follow-up data are available on 1659. At baseline, recognized risk factors for stroke were similar between the two treatment groups.

Intervention.—Daily aspirin administration and medical risk factor management for all patients; carotid endarterectomy for patients randomized to receive surgery.

Main Outcome Measures.—Initially, transient ischemic attack or cerebral infarction occurring in the distribution of the study artery and any transient ischemic attack, stroke, or death occurring in the perioperative period. In March 1993, the primary outcome measures were changed to cerebral infarction occurring in the distribution of the study artery or any stroke or death occurring in the perioperative period.

Results.—After a median follow-up of 2.7 years, with 4657 patient-years of observation, the aggregate risk over 5 years for ipsilateral stroke and any perioperative stroke or death was estimated to be 5.1% for surgical patients and 11.0% for patients treated medically (aggregate risk reduction of 53% [95% confidence interval, 22% to 72%]).

Conclusion.—Patients with asymptomatic carotid artery stenosis of 60% or greater reduction in diameter and whose general health makes them good candidates for elective surgery will have a reduced 5-year risk of ipsilateral stroke if carotid endarterectomy performed with less than 3% perioperative morbidity and mortality is added to aggressive management of modifiable risk factors.

Secondary objectives were to determine the surgical success in lesion removal and the incidence of recurrent carotid stenosis, the rate of progression or regression of carotid atherosclerosis in the medically treated comparison group, and the incidence of all other vascular events, such as TIA, myocardial infarction, and death related to vascular disease during follow-up.

METHODS

The design and organization of the ACAS are detailed elsewhere. Thirty-nine clinical centers were chosen from an applicant pool of 55. All obtained institutional review board approval of the study protocol.

Recruitment

Study participants were recruited from ultrasound vascular laboratories, practicing physicians who auscultated carotid bruits, and physicians who found carotid stenosis during evaluation for peripheral vascular or contralateral CEA.

Inclusion criteria were age between 40 and 79 years; compatible history and findings on physical and neurological examinations; performance of required laboratory and electrocardiographic examinations no earlier than 3 months before randomization; patient accessibility and willingness to be followed for 5 years; and valid informed consent.

Exclusion criteria were cerebrovascular events in the distribution of the study carotid artery or in that of the vertebrobasilar arterial system; symptoms referable to the contralateral cerebral hemisphere within the previous 45 days; contraindication to aspirin therapy; a disorder that could seriously complicate surgery; or a condition that could prevent continuing participation or was likely to produce disability or death within 5 years. (Detailed information regarding eligibiliti...
ity and exclusion is available on request from the corresponding author.)

The ACAS definition of hemodynamically significant carotid stenosis required that at least one of three criteria was met: arteriography within the previous 60 days indicating stenosis of at least 60% reduction in diameter (if the arteriogram was performed 61 to 364 days before randomization, Doppler ultrasonography was required to verify that the artery had not occluded); Doppler examination within the preceding 60 days showing a frequency or velocity greater than the instrument-specific cut point with 95% positive predictive value (PPV); or Doppler examination showing a frequency or velocity greater than the instrument-specific 90% PPV cut point confirmed by ocular pneumoplethysmographic (OPG-Gee) examination performed within the previous 60 days.

A patient could enter the study with unilaterally or bilaterally asymptomatic, hemodynamically significant stenosis, but only one artery was the study artery. If two arteries were eligible, the one with the greater stenosis was selected. If the stenoses were identical, the left carotid artery was chosen. Patients randomized to surgery on the basis of Doppler or Doppler with OPG-Gee were required to have an arteriogram prior to CEA. If a postrandomization arteriogram revealed the contralateral artery to have the greater stenosis, it then became the study artery. The nonstudy artery was managed medically unless a cerebrovascular event occurred, at which time CEA could be considered.

**Arteriographic Measurements**

The minimal residual lumen (MRL) and the distal lumen (DL) were measured on the same radiograph. The MRL was the smallest lumen diameter at the site of the stenotic lesion. The DL was the diameter at the first point distal to the MRL at which the arterial walls became parallel. Percentage of stenosis was calculated as 100 × (1 – [MRL/DL]).

**Ultrasound Measurements**

Because of the heterogeneity among ultrasound devices and techniques, we established a cut point for each by comparing Doppler ultrasonography with arteriograms performed within 42 days of each other. Doppler cut points were computed for peak systolic frequency or, if indeterminate, end diastolic frequency, based on data from 50 consecutive patients.

**Randomization**

An ACAS neurologist and an ACAS surgeon gave joint approval for entering patients. Once the eligibility criteria had been confirmed and after informed consent was obtained, the patient was randomized using the permuted block method with at least three different block sizes determined randomly, stratified by center, gender, number of eligible arteries, and previous contralateral CEA. The assignment category was communicated to each clinical center by the statistical coordinating center through an individualized computer program arranged so that the clinical center could neither predict nor reject an assignment.

**Medical Treatment**

All patients received 325 mg of regular or enteric-coated aspirin daily (provided by Sterling Health USA, New York, NY.). Stroke risk factors and their modification were reviewed with all patients at the time of randomization and again during subsequent interviews and telephone follow-up. This included discussion of diastolic and systolic hypertension, diabetes mellitus, abnormal lipid levels, excessive consumption of ethanol, and tobacco use. Whenever possible, the recommendations of the ACAS Risk Factor Reduction Committee were followed (available on request from the corresponding author).

**Surgical Treatment**

In addition to 325 mg of aspirin daily and risk factor modification counseling, patients randomized to the surgical arm received the normal evaluation and care of a surgical patient. They were scheduled to undergo CEA within 2 weeks of randomization. If an arteriogram or cranial computed tomogram (CCT) had not been performed, the patient underwent the procedure(s) before CEA. The arteriogram must have demonstrated a lesion of 60% or greater. Patients with a postrandomization, presurgical arteriogram demonstrating less than 60% stenosis or a distal abnormality such as aneurysm, arteriovenous malformation, or siphon stenosis exceeding the proximal stenosis did not undergo surgery but were retained in the surgical arm for comparison analyses. Asymptomatic cerebral infarction demonstrated by CCT was not an exclusion for surgery. No attempt was made to standardize or control anesthesia or surgical techniques used by the 117 ACAS-credentialed surgeons.

The surgeon, the ACAS neurologist, and the ACAS patient coordinator examined each patient 24 hours after CEA. All deficits occurring through the 30-day perioperative period required the administration of the end point review process (described below).

**Follow-up**

Follow-up evaluations were conducted at 1 month and thereafter every 3 months, alternating between clinic visits and telephone contacts. During the clinic visit, patients completed a medical history questionnaire and TIA/stroke questionnaire and underwent physical and neurological examinations and a Mini-Mental State Examination. Risk reduction management was reviewed and aspirin adherence was determined by pill count.

Doppler ultrasound studies were repeated at the 3-month follow-up, every 6 months thereafter during the first 24 months, then yearly, and at potential or verified end point or exit from the study after 5 years; CCT was repeated at potential end point or exit. Electrocardiogram was repeated when clinically indicated and at exit.

Patients were instructed to notify the coordinator if symptoms suggesting possible TIA or stroke occurred. The coordinator scheduled urgent evaluations by the ACAS neurologist and surgeon and activated the end point verification system.

In addition to identification of events from clinic visits and telephone contacts, hospital discharge diagnoses and death certificates were reviewed for coronary events and strokes.

**End Point Definition and Verification**

A TIA was defined as a focal ischemic neurological deficit of abrupt onset lasting at least 5 minutes and resolving completely within 24 hours. Deficits persisting longer than 24 hours were classified as stroke. All strokes or deaths occurring within 30 days after randomization in the surgical and 42 days in the medical groups were included as end points to reflect operative morbidity and mortality. The difference in times reflected an average 12-day interval between randomization and surgery.

Initial review was conducted under a stringent timetable involving one external expert masked for local diagnosis, treatment assignment, clinical center, and temporal relationship to surgery (if done). In addition, every potential event was abstracted, masked, and reviewed together by six experts on the End Point Review Committee. Our analyses are based on their diagnoses.

Secondary analyses considered any stroke and perioperative death; any stroke and any death; and any ipsilateral TIA and stroke and any peritensive TIA, stroke, or death. The ACAS used categories 2 through 5 of the Glasgow scale to determine a major stroke, defined as a stroke resulting in moderate or severe disability, persistent vegetative state, or death.

**Statistical Analyses**

Initially, the primary end points for evaluation of the two treatments were
The results of the Veterans Affairs trial demonstrated that CEA is preferable to medical management for preventing TIA in asymptomatic carotid stenosis, and the North American Symptomatic Carotid Endarterectomy Trial demonstrated that infarction following TIA is better managed surgically. Neither resolved the issue of whether CEA prevents unheralded cerebral infarction. Therefore, in March 1993, the ACAS Executive Committee and the Data and Safety Monitoring Committee voted to restrict the primary end point to stroke and perioperative complications or death.

For baseline comparisons, we used two-tailed t tests for comparing the means of continuous variables and χ² for comparing distributions of categorical variables, with no adjustment for multiple comparisons. Kaplan-Meier estimates of 5-year aggregate risk were compared between treatment groups using either Greenwood's formula for variances, for a large-sample test ignoring randomization stratification, or randomization tests, respecting randomization strata.

In the initial years of treatment comparison, 1991 through 1993, and subsequent years, the tests were for 2-, 3-, or 4-year aggregate risk. The randomization test was the primary method for interim treatment comparisons (see below). By the time of study closure, P values from the two methods agreed within .002, so that all test results and confidence intervals (CIs) reported are based on large-sample tests unless otherwise noted.

Semiannual treatment comparison analyses were used to advise the Data Safety and Monitoring Committee whether a significance boundary had been crossed. The stopping rule was a modified O'Brien-Fleming rule for maintaining the desired in a given stratum. From March 1988 through October 1993, 12,800 CEAs were performed at the sites. Six percent (683) were performed on "likely eligible nonrandomized" patients of ACAS physicians, 6% (758) were performed on already randomized ACAS patients, and the rest were performed on symptomatic patients, ineligible patients, or patients of surgeons not collaborating in the ACAS.

Patient characteristics are presented in Table 1. Of the 1662 randomized patients, three in the surgery group were lost to follow-up after randomization and are excluded from analysis, leaving 1569. The 825 surgical and 844 medical patients were compared for 189 baseline characteristics, with only six tests yielding nominal statistically significant differences at the .05 level. Two thirds of the patients were men, 95% were white, and 48% were aged 60 to 69 years. Mean age was 67 years; mean weight, 81 kg for men and 67 kg for women; mean systolic blood pressure, 146 mm Hg; mean diastolic blood pressure, 78 mm Hg; and mean total cholesterol concentration, 5.90 mmol/L (235 mg/dL). Approximately 75% of patients had a bruit associated with the study artery, and in 49%, a contralateral carotid bruit was heard; 21% had a previous myo-
cardiac infarction, and 21% a previous coronary artery bypass. Sixty-four percent had hypertension, 26% were cigarette smokers, and 23% had diabetes mellitus.

Four hundred seven patients (25%) had a previous hemispheric event, contralateral to the study artery, and 1155 (70%) were asymptomatic in the distribution of both arteries.

Thirty-nine percent of patients were randomized on the basis of an arteriogram showing at least 60% stenosis of the carotid artery. Fifty-five percent were randomized with a Doppler PPV cut point of at least 95%, and 6% with a Doppler cut point of at least 90% confirmed by OPG-Gee. The positive predictive value of Doppler, estimated from the postrandomization presurgery angiogram, was 98%.

Table 2 shows the distribution of percentage of stenosis for prerandomization and postrandomization arteriograms before CEA. Because the health status of patients who received prerandomization arteriograms may differ from that of those who did not, a weighted estimate based on both categories is included. Five percent of patients had stenosis of the randomized artery less than 70% to 79% stenosis; 25%, 80% to 89% stenosis; and 5%, 90% to 99% stenosis, which was 0.4% (95% CI, 0.0% to 0.8%).

All patients randomized to the surgical group were required to have arteriography. Of the 414 patients who underwent arteriography prior to CEA, five experienced a cerebral infarction, for an arteriographic complication rate of 1.2%. It is estimated that if all 724 patients receiving CEA had undergone arteriography as a part of the ACAS, 8.7 arteriographic cerebral infarctions would have occurred in addition to the 11 primary events in the 30 days following surgery.

Sixteen fatalities, potentially due to strokes, were reviewed by the Cerebrovascular End Point Review Committee. In no case was there a difference between the End Point Review Committee diagnosis and the local physician diagnosis. These events included six hemorrhagic strokes, two cerebral infarctions in the distribution of the randomized artery, three cerebral infarctions in the nonrandomized distribution, and five deaths not due to stroke.

### Treatment Comparisons

The study achieved its significance boundary after a median of 2.7 years of follow-up, with 8% of patients having completed 5 years; 20%, 4; 44%, 3; 65%, 2; and 37%, 1 year of follow-up. Because surgical patients were at greatest risk during the first month after endarterectomy, whereas the risk for medical patients was distributed throughout years, comparisons near term generally understated the differences expected after 5 years. Table 3 presents the observed number of events and also the Kaplan-Meier estimates predicted if all patients had been followed for 5 years. The estimated 5-year risk of ipsilateral stroke and any peroperative stroke or death was 11.0% for the medical group and 5.1% for the surgical group.

The reduction in 5-year ipsilateral stroke risk in the surgical group was 55% of the estimated 5-year risk in the medical group (95% CI, 22% to 72%). The P value for the test of the difference between the treatment groups in 5-year risk of primary event was .004 by the large-sample test and the randomization test for the primary end point of ipsilateral stroke and any peroperative stroke or death, the survival curves in the Figure cross near 10 months and become significantly reduced in the surgical group by 3 years. The reduction in 5-year ipsilateral stroke risk was 19% (95% CI, 12% to 26%) and in any stroke or death was 41% (95% CI, 32% to 49%).

### Table 2

<table>
<thead>
<tr>
<th>Event Type</th>
<th>Medical (n=834)</th>
<th>Surgical (n=825)</th>
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<tbody>
<tr>
<td>Ipsilateral stroke or any peroperative stroke or death</td>
<td>55</td>
<td>57</td>
</tr>
<tr>
<td>Major ipsilateral stroke or any peroperative major stroke or death</td>
<td>24</td>
<td>24</td>
</tr>
<tr>
<td>Ipsilateral TIA or stroke or any peroperative TIA or stroke or death</td>
<td>102</td>
<td>107</td>
</tr>
<tr>
<td>Any stroke or any peroperative death</td>
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<td>86</td>
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<tr>
<td>Any major stroke or peroperative death</td>
<td>40</td>
<td>37</td>
</tr>
<tr>
<td>Any stroke or death</td>
<td>135</td>
<td>127</td>
</tr>
<tr>
<td>Any major stroke or death</td>
<td>116</td>
<td>121</td>
</tr>
</tbody>
</table>

*CI indicates confidence interval; and TIA, transient ischemic attack.
all had an arteriogram performed before randomization, so the risk of stroke from undergoing an arteriogram was not included in the calculations. If a 1.2% arteriogram risk were added to the surgery groups at the three stenosis levels, the risk reductions become 0.35, 0.49, and 0.13, respectively, which are consistent with the overall results of the ACAS.

**COMMENT**

The ACAS was designed to test the efficacy of CEA for preventing ipsilateral stroke during a 5-year period. Even though this report includes patients followed up for a median of only 2.7 years, with 9% having completed 5 years of follow-up, the data demonstrate a statistically significant difference between the estimated 5-year ipsilateral stroke rates of 11.0% for the medical and 5.1% for the surgical group. Moreover, the results are in the same direction for all subgroups considered, including decades of stenosis (although not statistically significant because of small sample size), and for various secondary cerebrovascular end points. Furthermore, the results are virtually the same when restricted to all patients receiving the assigned treatment, and are almost identical for patients without previous contralateral symptoms or endarterectomy.

Approximately 70% of our medical and surgical patients had arteriographic stenoses less than 80%. Even so, the estimated 5-year ipsilateral stroke rate in the ACAS medical group was 11.0% (about 2.2% annually). The stroke rate in the medically managed group decreased to the lower end of the previously reported range, perhaps as a result of the medical management. The patients for this comparison group included six cerebral infarcts of the random distribution. The surgical group included six cerebral infarcts of the random distribution, stroke.

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result of vigorous risk factor management and exclusion of high-risk patients.

There were no significant differences in primary event rates between patient groups with and without symptoms or previous CEA of the contralateral carotid artery. With an annual mortality rate of 3.7%, approximately 89% of patients survived long enough to benefit from the protective effect of the operation, because the crossover in favor of surgery occurred within the first year.

Four other randomized prospective studies of CEA for asymptomatic carotid artery stenosis have been reported. One did not include stenosis exceeding 90%, another was terminated early because of excess cardiac events, and a third, the European Asymptomatic Carotid Surgery Trial, is ongoing.26

The fourth, the Veterans Affairs Cooperative Trial, randomized 444 patients and published results based on a mean follow-up of 47.9 months. The Veterans Affairs study differed from the ACAS in that only men were studied and all patients had an arteriogram.27 A third, the European Asymptomatic Carotid Surgery Trial, is ongoing.28

Like the Veterans Affairs trial, the ACAS showed an advantage for CEA in preventing TIA's, cerebral infarctions, and death in men. In addition, the ACAS showed an advantage in reducing the risk of ipsilateral stroke alone. Our results are consistent with others that established that symptomatic patients with carotid stenosis greater than 70% were best treated by CEA.21,29

Because a 10% difference in lumen diameter on arteriography is approximately 0.5 mm, and the lumen area stenosis difference is only 6%, this cannot be measured accurately, and when miniatrurized images are used, these differences cannot be discerned. Therefore, we believe that stenoses with 60% and 70% reductions in diameter are both significant, and that putative difference by decile is within the range of observer variability.30-32

It has been suggested that arteriography should have been required for all ACAS patients to ensure that only those with greater than 60% stenoses were entered. However, it was the judgment of the ACAS group that the hazards and costs of arteriography were not warranted for patients in our medical group. This was borne out by the 12% stroke rate from arteriography. Our Doppler criteria were established to maintain a PPV of 95%.33 Retrospective analysis of all post-randomization, presurgery arteriograms demonstrated that our actual PPV was 93%. This indicates that our medical patients did indeed have significant carotid artery stenosis, with fewer than 5% having less than the required 60%.

If all patients who underwent surgery had received arteriography as part of the surgical treatment, the absolute risk reduction would have been from 11.0% to 5.6%. Using ACAS eligibility requirements, 19 CEAs would be necessary to reduce 1% of stroke over 5 years.34 This ratio would be less if patient subsets at higher risk for stroke could be identified.

A CEA can be performed with a low complication rate even in elderly patients. In selected instances, some ACAS surgeons now operate without arteriography on the basis of noninvasive studies35 and sometimes discharge patients 24 hours following surgery.36 These and other measures may reduce costs if proved generally feasible.

CONCLUSIONS

The ACAS has demonstrated that the incidence of cerebral infarction can be reduced by CEA and that stringent quality control measures can reduce surgical morbidity and mortality. A major reason was the 30-day morbidity and mortality of ACAS patients, estimated to have been 2.7% if all surgery patients had undergone arteriography as part of the study. This includes arteriographic complications of 1.2%. These results may be improved further by reducing risk associated with contrast arteriography.
contrast arteriography. The ACAS has established that men with a good life expectancy who have asymptomatic carotid artery stenosis with at least 60% reduction in diameter are protected from stroke by CEA, whereas the results for women are less certain. Following CEA, the relative stroke risk reduction in men and women combined is 53%, with an absolute 5-year risk reduction from 11.0% to 5.1%. The 5-year reduction in stroke risk among men was 66% and among women 17%, perhaps because of the higher perioperative complication rate in women. Excluding arteriographic and periprocedural complications, the risk reduction was 79% for men and 56% for women.

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Columbia University, New York, NY [91]: J. P. Mohr, MD; Donald Quest, MD; Anneke Crum; Ralph Sacco, MD; T. K. Tatemichi, MD; Randolph Marshall, MD; Henning Mast, MD; Oscar Ramos, MD; James Correll, MD; Richard Lihman, MD; George Petty, MD; Anilda Cahmre, MD; Lorraine Grepeza, RVT, MD; Tira Gonzales.

University of Kentucky Chandler Medical Center, Lexington [88]: Byron Young, MD; Creed Pettigrew, MD; Ruthie Sadori, RN; Robert Dempsey, MD; Eric Endean, MD; Jerry Sherron, RVT; Mar­ dro Evelyn, MD; Jane Norton; Richard Lihman, MD; Michael McQuillen, MD; Sally Mattingly, MD; Steven Deokosky, MD; Andrew Massey, MD.

Hopital de l'Enfant Jesus, Quebec City, Quebec [90]: Denis Poirier, MD; Jean Turcot, MD; Cassandra Gallant, MD; Charlotte Benguigui, RN; Jacques Cote, MD (deceased); Jean-Marie Bouchard, MD; Claude Roberge, MD; Denis Brunet, MD; Bernard Fournier, MD; Audette Laperle, RN; Lajennese Jean Marc Bigioazet, RVT; Mamet Penit.

University of California at San Diego [78]: Patrick Lyden, MD; Robert Hye, RN; Stacy Lewis, RN; George A. Cappella, MD; Barbara G. David; Taft Alvarens, RN; John Rotbuck, MD; Mark Brody, MD; Richard Zwizer, MD; Mark Sedwick, MD; Bruce Stable, MD; Julie A. Freischlag, MD; Yohuda Alpert, MD; James Sivo; John Forych; Melody Adams.

Locopa University Medical Center, Maywood, IL [77]: William H. Baker, MD; Sudha Gupta, MD; Katy Craig, MD; Howard P. Greisler, MD; Fred N. Littosy, MD; Michael A. Kelly, MD.

University of Tennessee, Memphis [74]: James T. Robertson, MD; William Pulsipher, MD; Judith A. Campbell, RN, BSN; John Cockrell, MD; Claude Watridge, MD; J. Acker, MD; Samuel Eskander, MD; Michael Jacowisz, MD; Gail Walker; Patrick O'Sullivan, MD; Curtis Sauer, MD; Ken Yasu, MD; Kenneth Gallagher, MD; Mark Bertorini, MD; Susan Bennett, PA-C; Terry Thomas, DDS; Nan Stahl, RN; Connie Taylor, RN; Mary Ann Giampapa; Joan Connell; Judy Riley; Angelique Braddus, RN; Jennifer Gooden, RN; Nancy Newman; Rebecca Manning; Marcella McCreas.

University Hospital, London, Ontario [69]: Vladimir Hachinski, MD; Gary Ferguson, MD; Cheryl Mayer, RN; Henry J. M. Barton, MD; S. J. Peerless, MD; A. M. Buchan, MD; Howard Reichman, MD; Andrew Kertesz, MD; Stephen Lowhie, MD; Caroline White, RN; Allan Fox, MD; Richard Randin, MD; John L. Williams, MD; Jorge A. Furlong, MD; Andrew Massey, MD; Richard J. Terbruegge, MD.

Victria Hospital, London, Ontario [61]: J. David Spence, MD; H. W. K. Barr, MD; Leslie Puddock-Ellisaw, RN; L. P. L Assis, MD; J. H. W. Pexman, MD; Mary Decire, RVT; Barb Taie, RN; Caroline James, RVT.

Virginia Mason Clinic, Seattle, Wash [57]: Edward Raker, MD; James Cosworth, MD; Sandy Hilmoe, MD; Thomas Leitman, MD; Dennis Hendhicks, RN; John Benes, RVT; Thomas Leitman, MD; Kathy Butler-Levy; Robert Crane, MD; David Fryer, MD; James MacLain, MD; Laird Patterson, MD; Terence Quigley, MD; John Ravits, MD; Logan Varnsdorf, RVT; James M. Purcell, MD; Fabrice Sharpe, RVT; Shannon Boswell, RVT; Karen Kenty, RVT, RMT.

University of Cincinnati Ohio [56]: Thomas Brott, MD; Joseph Broderick, MD; Thomas Tomesek, MD; Lauri Sauereik, RN; L. F. Ederersteinier, MD; Richard Piov, MD; John Tow, MD; Richard Kempczinski, MD; Robert Reed, MD; Richard Welling, MD; Christine Blum, RN; Bill Schmealer, RN.

Bowman Gray School of Medicine of Wake Forest University, Winston-Salem, NC. [52]: Mark Levkoftiz, MD; J. Michael McWhorter, MD; Charles L. Браун, MD; Jean Satterfield; Robert Cordell, MD; Richard Dean, MD; George Flax, MD; Gary Hamilton, MD; Sherry Parson, MD; James Walker, MD; Cathy Nunn, RN, RVT; Larry Myers, MBA, RMTS, RVT; Charles Tegeler, MD; Sharon Hardin, RVT, RCVS; Dana Meads, RT, RVT.

University of Iowa Hospitals and Clinics, Iowa City [49]: Harold P. Adams, Jr., MD; Christopher M. Loftus, MD; Lynn A. Vining, RN; Birgette H. Bentzen, MD; Josef Bily, MD; John D. Cor­ dent; Margaret Dickson, MD; John C. Gotsi, MD; David L. Gordon, MD; Michael R. Jacoby, MD; Laurence J. Kappelle, MD; Timothy F. Kreshofi, MD; E. Eugene Marsh II, MD; Betzy S. Love, MD; Asai, R. Shamsa, MD; Karla J. Grimmman, MD; Dawn J. Marke, RN; Ed V. Miller, RVT.

Johns Hopkins Bayview Medical Center, Baltim­ more, MD [46]: Constance Johnson, MD; CVS Jones, MD; Brenda Stone, CSNP, MA; Pat Maguire, RN; Christopher Earley, MD; Peter Kaplan, MD; John Cavalluzi, MD; Gerald Waters, PA-C; Betty Chachich, RN.

S. M. Reimhorst, MD, St. Louis, MO (44): Arthur Auer, MD; William Logan, MD; Mary Wilcox, RN, BSN; Barbara Green, MD; Joseph Hurley, MD; Richard Pennell, MD; John Wood, MD; John F. Lewis, MD; Jeffrey Drayer, MD; Jack F. Ober­ frey Thomasson, MD; Claire Blackburn, RN, RVT; Marcia Foldes, RVT, BSN; Kathy Kemp, RN, RVT; Becky Naglieri, RT, RVT; Karen Rutherford, RT, BSN; Rdna, RN; Jena Hogan, RN, RVT; Lynne Thorpe, RN, RVT.

University of Arizona Health Sciences Center, Tucson [42]: William M. Feinberg, MD; Glenn C. Hubbard, MD; Margaret D. Leifer, MD; Victor M. Bernhard, MD; Kenneth E. McFirst, MD; L. Philip Carter, MD; Scott S. Berman, MD; Joseph L. R. Mills, MD; Enrique L. Labadie, MD; Darryl S. Johnson, MD; Catherine J. Rosen, MD; Robert H. Hamilton, MD; Scott Fors, MD; Joachim F. Seeger, MD; Raymond F. Carمؤ, MD; Brenda K. Vold, RN, BSN; Richard L. Carlson, Joan E. La­ guna, John P. Kriawicz, Jennifer J. Devine, BSN, RVT; Amanda M. Carstillos; Sheryl K. Kistler, RT, RVT; Betty Ledbetter; Kathleen (Sue) Dorr.

University of Mississippi Medical Center, Jackson [39]: Robert E. Smith, MD; Armin P. Haerer, MD; Robin L. Brown, BSN; WN Russell, MD; Edward Rigdon, MD; Robert Rhodes, MD; Evelyn Smith, RT; Michael Graeber, MD; David Donaldson, MD; S. H. Subramony, MD; David L. Gordon, MD.

Milson S. Hershey Medical Center, Hershey, PA [35]: Robert G. Altnuk, MD; Robert W. Brennan, MD; Luis H. Dunho, MD; Michael M. Hac, MD; No­ myer, RVT; Brrt L. Thiele; Florence Smith, RN; John D. Barr, MD; R. Bradford Duckrow, MD; Cindy Janesty, MD; Jon W. Melistrup, MD; Kevin P. McNamara, MD; Lawrence D. Rodick, MD; Leslie Stewart, MD; Maureen Sullivan, MD; Mark Wengrovitz, MD.

University of Texas Southwestern Medical Center, Dallas [35]: L. John Delacarte, MD; Hol Ul mapView, MD; Wilson Bryan, MD; Chris Mackins; Carolyn Patterson; Candy Alway, RDMS; Patty Boyd; Mary Inman, RN; Christie Albisun; Eva Scoggin; John Swwling.

University of California at Los Angeles (35): Wesly S. Moore, MD; Stanley N. Cohen, MD; Kathleen G. Walden, RN; Samuel S. Alin, MD; Ed­ den G. Smith, MD; Mia J. Ponsford, MD; Michael H. Doldin, MD; Carlos E. Donayre, MD; Julie A. Freischlag, MD; Hugh A. Gelaert, MD; Sheldon E. Jordan, MD; Herbert J. Machleder, MD; William J. Quillen, MD; Marilyn Cramer, MD; Jeffrey L. Savar, S.C.; Saui M. El-Saden, MD; Richard C. Holgate, MD; Bradley A. Jobour, MD; J. Bruce Jacobs, MD; Theresa M. Abraham, RN; Canuace L. Vesca.
RN: Jeanine A. von Rajcs, RN; Vicki L. Carter, RN; Jean-Claude Gautier, MD; Michael J. G. Harrison, MD; Jean-Marc Lacombe, MD; John Porcile, MD; Anthony P. Ambrose, MD; Diane K. DeWitt, MD; Robert S. Aron, MD; Di Woon, MD; Marc Chimowitz, MD.

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