

Training, competency, and credentialing standards for diagnostic cervicocerebral angiography, carotid stenting, and cerebrovascular intervention

A Joint Statement from the American Academy of Neurology, the American Association of Neurological Surgeons, the American Society of Interventional and Therapeutic Neuroradiology, the American Society of Neuroradiology, the Congress of Neurological Surgeons, the AANS/CNS Cerebrovascular Section, and the Society of Interventional Radiology*

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Appropriate and adequate cognitive and technical training, proficiency and experience are essential for the safe performance of procedures that confer significant risk to patient well-being. This principle is the foundation of all medical education and is especially important when considering the cerebral vasculature, for which stroke is a defined risk for every endovascular procedure. Despite recent advances in noninvasive diagnostic neuroimaging, diagnostic cervicocerebral angiography remains the cornerstone and “gold standard” for the evaluation and treatment of patients with cerebrovascular disease.¹ In addition to a high level of technical expertise, performance and interpretation of diagnostic cervicocerebral angiography requires in-depth cognitive knowledge of related neurological pathophysiology, neurovascular anatomy and pathology, and an understanding of the full range of neurodiagnostic possibilities. Expert diagnostic cervicocerebral angiography is the founda-

tion for safe and successful cervicocerebral endovascular intervention, including carotid artery angioplasty and stenting for atherosclerosis, interventional stroke therapy, intracranial angioplasty and stenting, and embolization of cerebral aneurysms, epistaxis and vascular malformations. All of these procedures are increasing in volume and complexity with recent technological advances that further mandate the need for adequate cognitive acumen and technical skills. To ensure proper outcomes, formal neuroscience training, adequate procedural training and sufficient experience are all essential for competency in diagnostic cervicocerebral angiography and interventional procedures, including carotid stenting. These concepts have been delineated in training requirements by the Accreditation Council for Graduate Medical Education (ACGME) and by previously published official society statements. The purpose of this document is to define the minimum training and

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*These organizations represent all clinical medical specialties with formal accredited ACGME-approved training in the cervicocerebral vasculature and associated neurological pathophysiology. The executive committees and governing bodies of each organization have approved this document.

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experience necessary to provide adequate quality of patient care for extracranial cerebrovascular interventions, particularly carotid artery stenting. Hospital credentialing is the mechanism by which competence is ensured.

Risks of cervicocerebral angiographic procedures. *Risks of diagnostic cervicocerebral angiography.* Stroke is recognized as the most disabling and costly of all medical conditions.² Stroke is also the most feared of all iatrogenic medical and procedural complications. The risk of procedure-induced stroke may be a reason not to recommend the test for many physicians, and contributes to the reluctance of some patients to undergo the procedure.³⁻⁶ For medical and ethical reasons, any procedure that has “stroke” as a defined risk should be performed only by medical professionals with appropriate training and experience.

The risk of permanent neurological deficit as a result of diagnostic cerebral angiography is considerable and ranges from 0.3–5.7%.^{5,7-20} Experienced neurovascular specialists may have complication rates lower than 1%.²⁰ There is additional risk of temporary neurological deficit ranging from 0.3–6.8% with, on average, a 2–3 fold increased risk of temporary as compared to permanent neurological deficit.⁷⁻²⁰ Patients with atherosclerotic cerebrovascular disease as manifested by neurological symptoms (ipsilateral transient ischemic attack [TIA] or stroke) have a 2–3 fold higher risk of stroke from diagnostic cerebral angiography (0.5–5.7% risk of permanent deficit) as compared to asymptomatic lesions (0.1–1.2% risk).^{5-10,15-20} In one study, 1000 consecutive patients undergoing diagnostic cerebral angiography were assessed for procedure-related neurological deficits.⁵ The overall stroke rate was 1%. However, 9 of the 10 patients experiencing neurological complications had a history of prior stroke or transient ischemic attack and the tenth had an “asymptomatic” bruit.⁵ Therefore the highest level of practitioner training should be required for patients with prior symptoms, who are at highest risk for angiographic complications.

Operator experience as measured by decreased complications and decreased fluoroscopy time necessary for the exam improves in a linear fashion up to 100 cases.¹⁰ Analysis of the trainee learning curve suggests that 200 exams are necessary for a physician to become a competent and secure examiner of the carotid and intracranial vasculature.¹⁰ Operator risk factors for angiographically produced ischemic complications (temporary and/or permanent stroke) are well known and include increased procedure and fluoroscopy time, increased number of catheters used, and performance of arch aortography.⁶⁻⁸ Performance of arch aortography may lead to greater numbers of emboli thus leading to higher procedure complication rates than selective carotid angiography and is not infrequently performed by less well-trained practitioners.^{8,21} All of the above-mentioned factors, including procedural time and multiple cath-

eter use, are not independent and are typically related to inexperience and lack of specialized training in the cervicocerebral circulation.^{8,12} The effect of training and experience, and/or lack thereof, was clearly shown in a 5000-angiogram analysis that demonstrated that fellowship-trained specialists have fewer neurological complications (0.5%) than even experienced angiographers (0.6%), and both have far fewer complications than trainees under supervision (2.8%).^{7,18,19} In the Asymptomatic Carotid Atherosclerosis Study (ACAS), the rate of stroke as a complication of diagnostic cerebral angiography was approximately 1.2%.¹⁷ This may be greater than the actual risk of stroke caused by the stenosis itself for many patients with asymptomatic stenosis.¹⁷ Indeed, this fact has led some vascular surgeons to suggest that diagnostic cervicocerebral angiography even when performed by well-trained neurovascular specialists may be too dangerous for the indication of asymptomatic carotid artery stenosis.²² However, more recent data has confirmed that the rate of stroke during routine diagnostic cerebral angiography when performed by appropriately trained and experienced neurovascular specialists is less than half the rate reported in ACAS.²⁰

Clinically obvious stroke may be the tip of the iceberg regarding complications of cervicocerebral angiography. “Silent” neuropathological sequelae of cerebral embolism are even more common than overt, clinically demonstrable neurological complications.^{20,21,23-25} The fact that thromboembolic occurrences may be “silent”, yet still represent serious pathologic brain damage has recently been described in two magnetic resonance imaging (MRI) studies where diffusion weighted pulse sequences ideal for detecting small infarcts were obtained after angiography.^{23,24} In one study, small new areas of brain infarction without overt clinical correlates were identified in 25% of 66 patients after diagnostic cerebral angiography.²³ Detection of apparent embolic insults by MRI was more common in cases with longer fluoroscopic/procedural times ($p < 0.01$) and was associated with the use of multiple catheters ($p = 0.02$).²³ Both of these parameters have been shown to be associated with sub-optimal training and experience.²⁴ “Subclinical” infarcts have been shown to result in cognitive deficits on neuropsychological testing after endarterectomy as well as carotid artery stenting.²⁵ Similar procedural injury to the heart has been extensively documented secondary to coronary interventions by measurements of elevations in troponin levels (so-called troponin “leak”) and constitutes justification for the current stringent training standards for coronary intervention.^{26,27}

In addition to the technical risks of cerebrovascular procedures, there is also a risk of misdiagnosis if images are not interpreted correctly. This fact justifies formal and adequate cognitive training related to neurological and neurovascular anatomy, neurodiagnostic imaging, and neuro-pathophysiology. Physicians must be able to accurately identify stroke and

TIA etiologies and evaluate traumatic and/or atherosclerotic neurovascular lesions and inflammatory conditions of the central nervous system. Evidence from numerous studies of coronary angiography performed by trained cardiologists demonstrates errors between observers' assessments ranging from 15% to 45% for evaluating essentially only one variable, ischemic vascular disease.²⁸ The ramifications of interobserver variation are considerable. If readings are erroneous, some patients will undergo interventional procedures unnecessarily, others might be denied an essential treatment, while still other patients may have pathological findings that are totally unrecognized.²⁸ The implications of this degree of variability for patients with cerebrovascular conditions are significant when considering that physicians may be performing and interpreting cervicocerebral angiography outside of their primary specialty training and may then be performing interventions that have stroke as a defined potential risk. Even if a cervicocerebral arteriogram is performed solely for assessment of extracranial carotid occlusive disease, unexpected findings (vasculitis; congenital vascular malformations; tumors; mass effects; embolic complications; acute, subacute, or chronic dissection as opposed to atherosclerotic disease; aneurysms; arteriovenous fistulae, etc.) require extensive neurodiagnostic and neuroangiographic knowledge and interpretive skills which can only be obtained with appropriate formal training.

Risks of cervicocerebral interventional procedures. Endovascular interventions carry a higher risk than diagnostic angiography in all vascular beds. The American College of Cardiology (ACC) has recognized this by requiring physicians to complete diagnostic coronary angiography training prior to beginning interventional coronary training.²⁹ The risk of elective carotid stenting is greater than the risk associated with elective coronary intervention, which is typically less than 2% for emergency coronary artery bypass surgery and less than 2% for death.^{30,31} Randomized controlled trial data indicate stroke and death rates for carotid stenting ranging from 4.4% to over 12% at 30 days, with a one-year stroke and death rate of up to 12%.³²⁻⁴¹ MRI examinations demonstrate detectable ischemic lesions in 22% to 29% of brains after carotid stenting.^{42,43} Additionally, a significant learning curve for carotid stenting has been clearly documented.⁴⁴

Potential benefit from "embolism protection" devices might render carotid stenting safer than is currently documented, but procedural stroke and death rates still range from at least 2.8% in one registry to over 6% at 30 days in other unpublished registries for both asymptomatic and symptomatic patients.^{34,36,37,40} Indeed, in two randomized controlled trials comparing stent procedures with "protection" and with "no-protection", there was conflicting evidence concerning protection, with one trial indicating no difference and the other actually demonstrating worse outcomes "with protection."⁴⁵⁻⁴⁷ Possible efficacy of "protection" devices has been

demonstrated in at least one registry, in the carotid stenting arm of an endarterectomy versus stenting trial, and in a review article.^{40,48,49} Therefore, for carotid stenting, the conflicting proof of efficacy for protection devices, proven failure to eliminate all complications including stroke or death, and demonstrated patient risk greater than elective coronary intervention, for example, reaffirms that carotid stenting be performed only by individuals with sufficient cognitive neuroscience knowledge coupled with sufficient training and experience and subsequent excellent procedural technique, as described herein.

Cervicocerebral intervention not only includes carotid artery and extracranial angioplasty and stenting but also intracranial angioplasty and stenting as well as other therapies. The risks of neurological complications from intracranial angioplasty and stenting and cerebral aneurysm coiling are substantial. The reported neurological complication rate for intracranial angioplasty and stenting ranges from 5% in 30 days to 36%.⁵⁰⁻⁵⁹ A significant learning curve has been demonstrated for coiling of cerebral aneurysms and the reported neurological complication rate ranges from 5% to 14%.⁶⁰⁻⁶⁴ Similar to the findings in carotid stenting, diffusion-weighted MRI reveals a higher rate of distal embolization associated with this procedure (up to 61%) than overt symptoms; many of the emboli are "silent."^{21,23,24,65}

Training. Introduction. Official standards of training for all specialties have existed for over a quarter century, are the hallmark of medical licensure, board examinations and residency programs, individual physician privileges and hospital credentialing, and are recognized as vital by the Accreditation Council for Graduate Medical Education (ACGME), the Federation of State Medical Boards of the United States, Inc., the American Board of Medical Specialties (ABMS), and the National Board of Medical Examiners® (NBME®).⁶⁶⁻⁶⁸ Furthermore, continuing assessment of competence is mandated by the Centers for Medicaid and Medicare Services as well as state medical licensing boards in the form of Continuing Medical Education (CME) credits.⁶⁹⁻⁷¹ The Joint Commission on Approval for Healthcare Organizations (JCAHO) is working with two other accrediting organizations, the National Committee for Quality Assurance and URAC (formerly known as the Utilization Review Accreditation Commission), on coordinating and aligning patient safety standards.⁷²⁻⁷⁴ JCAHO has established guidelines for primary stroke centers based on Brain Attack Coalition recommendations that include quality of service standards for diagnostic cervicocerebral angiography.⁷⁵ The Brain Attack Coalition has also established guidelines for Comprehensive Stroke Centers that mandate cognitive and technical neurovascular training and expertise in order to perform carotid stenting (Alberts MJ, Latchaw RE, Selman WR, et al. Recommendations for Comprehensive Stroke

Centers: A Consensus Statement from the Brain Attack Coalition. Submitted for publication.).

Training guidelines for diagnostic arteriography and endovascular intervention are necessary for optimal and safe patient care and have been formulated and officially stated by numerous medical societies, including the American Heart Association (AHA), the ACC, the Society for Vascular Surgery (SVS), the Society of Interventional Radiology (SIR), the American Society of Neuroradiology (ASNR), and the American Society of Interventional and Therapeutic Neuroradiology (ASITN).⁷⁶⁻⁹⁸ These AHA, ACC, SVS, SIR, ASNR, and ASITN guidelines mandate at least 100 diagnostic angiograms regardless of the vascular bed. The fact that there are varying degrees of difficulty for certain procedures and that these procedures thus impart associated degrees of risk to the patient has also been specifically recognized and summarized by the ACC.⁷⁹ For example, in recognition of the critical nature of certain catheter based procedures, the ACC has published the Revised Recommendations for Training in Adult Cardiovascular Medicine Core Cardiology Training II statement (COCATS 2).²⁹ In addition to the required minimum 24 clinical months of training by COCATS 2, diagnostic coronary catheterization mandates a minimum of 8 dedicated months in a cardiac catheterization laboratory during training in the pathophysiology and treatment of heart disease with specific requirements for approved supervised training on at least 300 diagnostic coronary angiograms before a practitioner is judged competent for credentialing purposes.²⁹ This same concept is at least as important when dealing with the cerebral vasculature and the performance of cervicocerebral angiography.

The ACC has determined that cognitive training about the pathophysiology of the heart in addition to credentialing in diagnostic coronary angiography is a prerequisite for training in coronary intervention.^{80,84,86,87} Furthermore, in addition to the core 24 month training period and 300 diagnostic coronary angiograms, the ACC recommends a full 20 months of supervised cardiac catheterization lab training with at least 250 supervised coronary stent procedures as the minimum acceptable requirements before a practitioner is judged competent to perform coronary interventions.⁸⁸⁻⁹² The ABMS has not only affirmed that high degrees of training are necessary for appropriate and safe cardiac patient care but acknowledged this high level of achievement in the form of a Certificate of Added Qualification (CAQ) for Interventional Cardiology.⁹⁹ These same principles are necessarily as crucial for the performance of interventional procedures relating to the cervicocerebral vasculature, including carotid stenting.

Existing standards. Cognitive training in cerebrovascular disease. The American Board of Radiology examinations for Diagnostic Radiology include written and oral subspecialty evaluation of neurodiagnostic imaging, and neurological and neurovascu-

lar anatomy and pathophysiology.¹⁰⁰ This cognitive knowledge base includes stroke syndromes and TIA etiologies, evaluation of traumatic and/or atherosclerotic neurovascular lesions, and inflammatory conditions of the central nervous system.

The range and complexity of neuroradiology, neurodiagnostic imaging and cervicocerebral angiographic procedures is such that this has been recognized by the ABMS in the form of a CAQ in Diagnostic Neuroradiology.¹⁰¹ This training mandates a minimum of an entire additional year of formal ACGME-approved training beyond the radiology residency and this knowledge is formally tested with an oral examination.¹⁰¹ This depth of knowledge and experience is unachievable in a casual or informal setting.

Due to the extensive body of knowledge in the medical discipline related to cervicocerebral pathophysiology and its clinical manifestations, an entire year beyond residency in Neurology is required to achieve competence in Vascular Neurology. The complexity of this field of study of patients with cerebrovascular disease is further affirmed by the creation of the new ACGME-approved subspecialty of Vascular Neurology.¹⁰² Only after completing one year of Vascular Neurology training with additional training in neuroradiology can the neurology applicant enter into training in Endovascular Surgical Neuroradiology (ESN).¹⁰³ The body of knowledge and skill obtained during the minimum of these two full years of additional dedicated formal postgraduate training after completion of a complete neurology residency are not achievable in a casual or informal setting.

Diagnostic cervicocerebral angiographic training. The ACC and AHA recognize that adequate cognitive knowledge of the heart is a mandatory foundation for performance of coronary angiography and intervention and mandate 24 months as minimum cognitive training period.²⁹ The clinical neuroscience societies herein, in agreement with the principles espoused by the ACC and AHA, believe that adequate cognitive knowledge of the brain is a mandatory foundation for performance of diagnostic cervicocerebral angiography and intervention. The cervicocerebral vasculature is technically demanding and clinically unforgiving and mandates competence in the performance of any procedures involving this vasculature. In recognition of this fact, the American Academy of Neurology has published guidelines for cervicocerebral angiography that recommend 100 appropriately supervised cervicocerebral angiograms as a minimum for required training and credentialing for this invasive procedure.^{95,96} Training and quality improvement guidelines for adult diagnostic cervicocerebral angiography have been officially formulated and published by the American College of Radiology, the ASITN, the ASNR and the SIR.^{77,82} Radiology and its subspecialty neuroradiology were formerly the only medical specialties that incorporated cervicocerebral angiography into ACGME-approved residency training programs.^{101,104} Cervicocerebral

angiography and intervention is now included in the new ACGME-approved Endovascular Surgical Neuro-radiology training program that includes physicians from neurosurgery, neurology, and neuroradiology.¹⁰³

Interventional cervicocerebral training. The ACC, the AHA, and the SIR have published guidelines requiring 100 diagnostic angiograms for credentialing in *peripheral* vascular angioplasty.^{76,78-81} These AHA, ACC, and SIR standards mandate competence regardless of subspecialty background and/or endovascular experience in any other vascular bed, including the heart.

In recognition of the complexity and critical nature of interventional cervicocerebral procedures, the American Association of Neurological Surgery (AANS), the Congress of Neurological Surgeons (CNS), the AANS/CNS Cerebrovascular Section, the American Society of Interventional and Therapeutic Neuroradiology, and the American Society of Neuroradiology published a unanimously endorsed statement specifying training requirements for the safe endovascular treatment of conditions that affect the brain, including the procedure of carotid stenting.⁹⁷ These *Program Requirements for Residency/Fellowship Education in Neuroendovascular Surgery/Interventional Neuroradiology: A Special Report on Graduate Medical Education* mandate 100 diagnostic cervicocerebral angiograms prior to training in this neurointerventional specialty, similar to the mandated requirements of COCATS 2.²⁹ This requirement is not altered by prior angiographic experience in any other vascular territories.

The ACGME has given its highest form of recognition for the need for advanced training for endovascular interventions involving the cervicocerebral and intracranial vasculature by officially recognizing the new discipline of Endovascular Surgical Neuroradiology.¹⁰³ The complexity of this medical/surgical discipline requires a minimum total of 7 to 8 years of dedicated formal postgraduate cognitive and procedural training with qualified supervision: far longer than most specialties. Appropriately prepared neurologists, neurosurgeons, and neuroradiologists are eligible to enter this ACGME training program. This ACGME-approved ESN training program explicitly incorporates additional training in clinical neurointensive care, as well as thorough training in advanced endovascular neuroradiological procedural techniques.¹⁰³ The ACGME-defined program of ESN specifically elucidates training in the indications, contraindications and technical aspects of carotid stenting for atherosclerosis.¹⁰³

Knowledge necessary for cerebrovascular intervention. Our collaborative neuroscience societies, in agreement with the principles espoused in the ACC COCATS 2, recognize the necessity of three components of adequate training for competency to perform cervicocerebral diagnostic and interventional procedures: 1) formal training which imparts an adequate depth of cognitive knowledge of the brain and its associated pathophysiological vascular processes, in-

cluding management of complications of endovascular procedures, 2) adequate procedural skill achieved by repetitive supervised training in an approved clinical setting by a qualified instructor, and 3) diagnostic and therapeutic acumen, including the ability to recognize and manage procedural complications, achieved by studying, performing and correctly interpreting a large number of diagnostic procedures with proper tutelage. Just as with diagnostic coronary angiography and coronary intervention, extensive knowledge of the brain and the ability to correctly *interpret* a cervicocerebral angiogram is the prerequisite and foundation for the *technical performance* of cervicocerebral angiography. The ability to adequately assess the array of diagnostic imaging studies of the brain with adequate knowledge of the numerous pathophysiological possibilities is a necessary attribute of any practitioner who would perform cervicocerebral procedures, irrespective of the primary specialty of the practitioner.

Although interpretative skills of imaging are essential, clinical cognitive skills related to the epidemiology, diagnosis, and management of patients with cervicocerebral vascular disorders are the sine qua non of quality patient care, safety, and treatment selection. All major industry and National Institutes of Health (NIH) sponsored trials related to carotid stenting and cervicocerebral interventions, including asymptomatic, symptomatic and high surgical-risk patients, have required an independent assessment by a board-certified neurologist. This assessment includes documented competency in performing a complete neurological evaluation including the NIH Stroke Scale. Consequently, we not only endorse this principle in general practice, but also mandate adequate training for all neuroendovascular practitioners that encompasses knowledge of stroke syndromes and includes formal training and competency in the NIH Stroke Scale.

Competence in recognizing any procedural complication and being able to offer the most appropriate treatment is one of the basic goals of adequate formal training, particularly concerning cervicocerebral angiography and/or intervention. This would include the ability to recognize clinical intra- or post-procedural neurological symptoms as well as pertinent angiographic findings and the proper cognitive and technical skills to offer the most appropriate therapy. While this therapy might entail intracranial endovascular rescue, it might also entail optimal hemodynamic management necessitating sufficient clinical neurointensive skills.

Our collaborative neuroscience societies recognize that practitioners from a variety of backgrounds may currently have or wish to develop endovascular skills. Our consensus is that a minimum amount of formal cognitive training specifically related to stroke and cerebrovascular disease is essential for any physician to perform diagnostic cervicocerebral angiography and interventional procedures. Therefore, in addition to procedural technical experience

requirements, a minimum of 6 months of formal cognitive neuroscience training in an ACGME-approved training program in radiology, neuroradiology, neurosurgery, neurology, and/or vascular neurology is required. This minimum formal training applies to all practitioners who wish to be credentialed to perform diagnostic cervicocerebral angiography and/or cervical carotid interventions, including practitioners from specialties with or without dedicated training in clinical neuroscience as part of their ACGME-approved residency programs.

Augmentation of training. Simulator training has been shown to be of benefit in limited medical applications.¹⁰⁵⁻¹¹² At the present time, appropriate formal training and experience in clinical cervicocerebral angiography and intervention in an approved clinical training program has no adequate substitute in contemporary medical practice, but future trainees may benefit from added training on medical simulators. At the present time, simulator equipment is neither perfected nor validated for training purposes concerning the cervicocerebral vasculature, but it is anticipated that eventually these technologies may offer up to, but not greater than, 20% of the required training experience in procedural technique. Our collaborative societies, consistent with ACGME training standards and the ACC training standards (COCATS 2), emphasize that industry-sponsored seminars, continuing medical education (CME) coursework, and self-taught learning are insufficient for credentialing related to diagnostic cervicocerebral angiography, extracranial interventions, intracranial interventions, or carotid stenting.

Maintenance and assurance of continuing quality of care. Procedures that have stroke as a defined potential risk require the highest level of competency. Proficiency is maintained by lifelong continuing medical education as well as continuing performance of cases with adequate success and outcomes with minimal complications. Quality Assurance and continuing improvement are necessary for high quality healthcare regardless of which discipline might be involved in treating patients. The quality improvement process is a patient oriented process, designed to ensure a baseline level of quality and predictable outcomes, and represents in many ways a safety net for the credentialing process. A post-hoc quality assurance process is no substitute for adequate and appropriate physician training leading to acceptably skilled practitioners suitable for credentialing. A quality assurance process should confirm that procedures are performed for appropriate indications with rates of success and complications that meet acceptable standards. Such Quality Improvement standards have been published for diagnostic cerebral angiography as well as extracranial carotid stenting.^{77,82,95,113} Such standards are necessary for quality assurance for procedures of such considerable consequence. The outcomes required by these standards should be achieved both during the training cases and following granting of credentials

in order to ensure maintenance of competence. At this time there is insufficient information to know if maintenance of competency requires annual performance of specific numbers of cases, but data from other vascular interventional procedures such as coronary stenting, coronary artery bypass grafting, and carotid endarterectomy indicate that, in general, greater experience confers better outcomes.¹¹⁴⁻¹¹⁶

Consensus of the collaborating neuroscience societies

- 1) All collaborating neuroscience societies are of the unanimous opinion that the safety of the patient is paramount.
- 2) Defined formal training and experience in **both** the cognitive **and** technical aspects of the neurosciences are essential for the performance and interpretation of diagnostic and therapeutic cervical and cerebrovascular procedures. Therefore, in addition to procedural technical experience requirements, a minimum of 6 months of formal cognitive neuroscience training is required in an approved program in radiology, neuroradiology, neurosurgery, neurology, and/or vascular neurology for any practitioner performing cervical carotid interventional therapy, including carotid stenting. This minimum neuroscience training recommendation applies to all practitioners, whether from specialties with or without dedicated training in the clinical neurosciences as part of their ACGME-approved residency programs.
- 3) All collaborating neuroscience societies endorse the principles of the several published standards from our various societies for training and quality concerning cervicocerebral angiography and intervention.^{77,82,95-97,113} We affirm the necessity for adequate and appropriate cognitive knowledge as well as adequate specialized procedural training and experience as described herein for credentialing in cervicocerebral angiography. Credentialing to perform (and in some cases interpret) cervicocerebral angiograms for one single purpose (e.g., evaluation of carotid occlusive disease) theoretically approves performance and interpretation for all purposes or neurovascular conditions without distinction, some of which (e.g., cerebrovascular trauma, vasculitis, congenital vascular malformations, tumors, mass effects, identification of embolic complications, differentiation of acute/subacute/chronic dissection from atherosclerotic disease, diagnosis of arteritides, identification of intracerebral aneurysms, etc.) clearly demand interpretive skills not conferred by casual training and experience. Therefore, limited credentialing for limited procedures with limited training is unacceptable.
- 4) All collaborating neuroscience societies recommend appropriately supervised cervicocerebral

angiography training and resultant credentialing with an accumulated total of 100 diagnostic cervicocerebral angiograms **before** postgraduate training in cervicocerebral interventional procedures, including carotid stenting, as described herein.^{29,97}

- 5) All collaborating neuroscience societies endorse the principles of training and quality assurance espoused in the multisociety *Quality Improvement Guidelines for the Performance of Carotid Angioplasty and Stent Placement*,¹¹³ which include a defined training pathway for any qualified practitioner for carotid stent training.
- 6) All collaborating neuroscience societies specifically endorse the principles of the ACGME and the training programs in Endovascular Surgical Neuroradiology,¹⁰³ Vascular Neurology¹⁰² and Neuroradiology.¹⁰¹

Conclusions. All medical societies directly or indirectly involved with cervicocerebral angiography concur in the necessity of quality and safety of patient care. Credentials committees at each hospital and institution must promote adequate standards of training and experience for initial accreditation in diagnostic cervicocerebral angiography that are uniform across all specialties, guarantee patient safety, and assure continuous high quality of performance. Furthermore, credentials committees should certify and enforce prospective quality improvement programs that are consistent with mandated and accepted training standards as defined by the ACGME, the American Medical Association, the ABMS, and individual state medical licensing boards. Credentials committees are expected to guarantee that individual physicians diagnosing and treating cerebrovascular disease with endovascular procedures have sufficient formal neuroscience training and experience as well as adequate training in the performance and interpretation of diagnostic cervicocerebral angiography and the implications of the varied potential findings so as to optimize the proper expected medical outcomes and assure patient safety. Due to the grave consequences of inadequate or deficient training, stringent credentialing criteria with formal neuroscience training as specified by published standards and as elucidated herein should be mandated for those performing carotid, vertebral, and intracranial cerebrovascular interventions, just as is the case with coronary interventions.^{83-94,97,113}

Appendix

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References

1. Science Advisory Committee. Cerebral angiography: a report for health professionals by the Executive Committee of the Stroke Council, American Heart Association. *Circulation* 1989;79:474.
2. Wein TH, Hickenbottom SL, Alexandrov AV. Thrombolysis, stroke units and other strategies for reducing acute stroke costs. *Pharmacoeconomics* 1998;14:603-611.
3. Berteloot D, Leclerc X, Leys D, et al. Cerebral angiography: a study of complications in 450 consecutive patients. *J Radiol* 1999;80:843-848.
4. Hankey GJ, Warlow CP, Molyneux AJ. Complications of cerebral angiography for patients with mild carotid territory ischaemia being considered for carotid endarterectomy. *J Neurol Neurosurg Psychiatry* 1990;53:542-548.
5. Heiserman JE, Dean BL, Hodak JA, et al. Neurologic complications of cerebral angiography. *AJNR* 1994;15:1401-1407.
6. Davies KN, Humphrey PR. Complications of cerebral angiography in patients with symptomatic carotid territory ischemia screened by carotid ultrasound. *J Neurol Neurosurg Psychiatry* 1993;56:9647-9672.
7. Mani RL, Eisenberg RL. Complications of catheter cerebral arteriography: analysis of 5000 procedures. II. Relation of complication rates to clinical and arteriographic diagnoses. *AJR* 1978;131:867-869.
8. McIvor J, Steiner TJ, Perkins GD, et al. Neurological morbidity of arch angiography in cerebrovascular disease. The influence of contrast medium and the radiologist. *Br J Radiol* 1987;60:117-122.
9. Earnest RL, Forbes G, Sandok BA, et al. Complications of cerebral angiography: prospective assessment of risk. *AJR* 1984;142:247-253.
10. Dion JE, Gates PC, Fox AJ, et al. Clinical events following neuroangiography: a prospective study. *Stroke* 1987;18:997-1004.
11. Moran CJ, Milburn JM, Cross DT, et al. Randomized controlled trial of sheaths in diagnostic neuroangiography. *Radiology* 2001;218:183-187.
12. Grzyska U, Freitag J, Zeumer H. Selective cerebral intraarterial DSA. Complication rate and control of risk factors. *Neuroradiology* 1990;32:296-299.
13. Horowitz MB, Dutton K, Purdy PD. Assessment of complication types and rates related to diagnostic angiography and interventional neuroradiologic procedures. *Interventional Neuroradiology* 1998;4:27-37.
14. Vitek JJ. Femorocerebral angiography: analysis of 2000 consecutive examinations, special emphasis on carotid arteries in older patients. *AJR* 1973;118:633-646.
15. Willinsky RA, Taylor SM, terBrugge K, et al. Neurologic complications of cerebral angiography: prospective analysis of 2,899 procedures and review of the literature. *Neuroradiology* 2003;227:522-528.
16. Kerber CW, Cromwell LD, Drayer BP, et al. Cerebral ischemia. I. Current angiographic techniques, complications, and safety. *AJR* 1978;130:1097-1103.
17. Executive Committee for the Asymptomatic Carotid Atherosclerosis Study. Endarterectomy for asymptomatic carotid artery stenosis. *JAMA* 1995;273:1421-1428.
18. Mani RL, Eisenberg RL, McDonald EJ Jr, et al. Complications of catheter cerebral angiography: analysis of 5000 procedures. I. Criteria and incidence. *AJR* 1978;131:861-865.
19. Mani RL, Eisenberg RL. Complication of catheter cerebral arteriography. Analysis of 5000 procedures. III. Assessment of arteries injected,

- contrast medium used, duration of procedure and age of patient. *AJR* 1978;131:871–874.
20. Johnston DC, Chapman KM, Goldstein LB. Low rate of complications of cerebral angiography in routine clinical practice. *Neurology* 2001;57:2012–2014.
 21. Dagirmanjian A, Davis DA, Rothfus WE, et al. Detection of clinically silent intracranial emboli ipsilateral to internal carotid artery occlusions during cerebral angiography. *AJR* 2000;174:367–369.
 22. Kuntz KM, Skillman JJ, Whittemore AD, Kent KC. Carotid endarterectomy in asymptomatic patients—Is contrast angiography necessary? A morbidity analysis. *J Vasc Surg* 1995;22:706–716.
 23. Bendszus M, Koltzenberg M, Burger R, et al. Silent embolism in diagnostic cerebral angiography and neurointerventional procedures: a prospective study. *Lancet* 1999;354:1594–1597.
 24. Britt PM, Heiserman JE, Snider RM, et al. Incidence of postangiographic abnormalities revealed by diffusion-weighted MR imaging. *AJNR* 2000;21:55–59.
 25. Crawley F, Stygall J, Lunn S, et al. Comparison of microembolism detected by transcranial Doppler and neuropsychological sequelae of carotid surgery and percutaneous transluminal angioplasty. *Stroke* 2000;31:1329–1334.
 26. Abbas SA, Glazier JJ, Wu AH, et al. Factors associated with the release of cardiac troponin T following percutaneous transluminal coronary angioplasty. *Clin Cardiol* 1996;19:782–786.
 27. Johansen O, Brekke M, Stromme JH, et al. Myocardial damage during percutaneous transluminal coronary angioplasty as evidenced by troponin T measurements. *Eur Heart J* 1998;19:112–117.
 28. Leape LL, Park RE, Bashore TM, et al. Effect of variability in the interpretation of coronary angiograms on the appropriateness of use of coronary revascularization procedures. *Am Heart J* 2000;139:106–113.
 29. Beller GA, Bonow RO, Fuster V. Core Cardiology Training Symposium (COCATS). ACC revised recommendations for training in adult cardiovascular medicine. Core Cardiology Training II (COCATS 2) (Revision of the 1995 COCATS training statement). *J Am Coll Cardiol* 2002;39:1242–1246.
 30. Jamal SM, Shrive FM, Ghali WA, et al. In-hospital outcomes after percutaneous coronary intervention in Canada: 1992/93 to 2000/01. *Can J Cardiol* 2003;19:782–789.
 31. Anderson HV, Shaw RE, Brindis RG, et al. A contemporary overview of percutaneous coronary interventions. The American College of Cardiology-National Cardiovascular Data Registry (ACC-NCDR). *J Am Coll Cardiol* 2002;39:1096–1103.
 32. Roubin GS, Yadav S, Iyer SS, Vitek J. Carotid stent-supported angioplasty: a neurovascular intervention to prevent stroke. *Am J Cardiol* 1996;78:8–12.
 33. Diethrich EB, Ndiaye M, Reid DB, et al. Stenting in the carotid artery: initial experience in 110 patients. *J Endovasc Surg* 1996;3:42–62.
 34. Wholey MH, Wholey M, Bergeron P, et al. Current global status of carotid artery stent placement. *Cathet Cardiovasc Diagn* 1998;44:1–6.
 35. Jordan WD Jr, Voellinger DC, Fisher WS, Redden D, McDowell HA. A comparison of carotid angioplasty with stenting versus endarterectomy with regional anesthesia. *J Vasc Surg* 1998;28:397–403.
 36. Yadav JS, Wholey MH, Kuntz RE, et al., and Stenting and Angioplasty with Protection in Patients at High Risk for Endarterectomy Investigators. Protected carotid-artery stenting versus endarterectomy in high-risk patients. *N Engl J Med* 2004;351:1493–1501.
 37. Wholey M. ARCHER Trial: one-month results. Presented at the Society of Interventional Radiology 29th Annual Scientific Meeting, Phoenix, March 25–30, 2004.
 38. Alberts MJ for the Publications Committee of the Wallstent Trial. Results of a multicenter prospective randomized trial of carotid artery stenting vs carotid endarterectomy. *Stroke* 2001;32:325. Abstract.
 39. Endovascular versus surgical treatment in patients with carotid stenosis in the Carotid and Vertebral Artery Transluminal Angioplasty Study (CAVATAS): a randomised trial. *Lancet* 2001;357:1729–1737.
 40. Wholey MH, Wholey M, Mathias K, et al. Global experience in cervical carotid artery stent placement. *Cathet Cardiovasc Intervent* 2000;50:160–167.
 41. Yadav J. SAPHIRE Trial: one year results. Presented at the Trans Catheter Therapeutics Meeting, Washington DC, September 15–19, 2003.
 42. Jaeger HJ, Mathias KD, Hauth E, et al. Cerebral ischemia detected with diffusion-weighted MR imaging after stent implantation in the carotid artery. *AJNR* 2002;23:200–207.
 43. Jaeger HJ, Mathias KD, Drescher R, et al. Diffusion-weighted MR imaging after angioplasty or angioplasty plus stenting of arteries supplying the brain. *AJNR* 2001;22:1251–1259.
 44. Vitek JJ, Roubin GS, Al-Mubarek N, et al. Carotid artery stenting: technical considerations. *AJNR* 2000;21:1736–1743.
 45. Mathias K. Results of European trials. Presented at the Society of Interventional Radiology 29th Annual Scientific Meeting, Phoenix, March 25–30, 2004.
 46. Macdonald S, Cleveland TJ, Gaines P, et al. Neuropsychometric outcomes of unprotected and protected carotid stenting (EmboShield™): a randomized trial. *J Vasc Intervent Radiol* 2004;15(2,Part 2):S184–S185. Abstract.
 47. Macdonald S, Cleveland TJ, Gaines PA, et al. Diffusion-weighted imaging (DWI) to compare protected and unprotected carotid stenting: a randomized trial. *J Vasc Intervent Radiol* 2004;15(2,Part 2):S185. Abstract.
 48. EVA-3S Investigators. Carotid angioplasty and stenting with and without cerebral protection. *Stroke* 2004;35:e18–e20.
 49. Kastrup A, Groschel K, Krapf H, et al. Early outcome of carotid angioplasty and stenting with or without protection devices: a systematic review of the literature. *Stroke* 2003;34:813–819.
 50. Lee JH, Kwon SU, Lee JH, et al. Percutaneous transluminal angioplasty for symptomatic middle cerebral artery stenosis: long-term follow-up. *Cerebrovasc Dis* 2003;15:90–107.
 51. Gress DR, Smith WS, Dowd CF, et al. Angioplasty for intracranial symptomatic vertebrobasilar ischemia. *Neurosurgery* 2002;51:23–27; discussion 27–29.
 52. Lylyk P, Cohen JE, Ceratto R, et al. Angioplasty and stent placement in intracranial atherosclerotic stenoses and dissections. *AJNR* 2002;23:430–436.
 53. Levy EI, Horowitz MB, Koebe CJ, et al. Transluminal stent-assisted angioplasty of the intracranial vertebrobasilar system for medically refractory, posterior circulation ischemia: early results. *Neurosurgery* 2001;48:1215–1221; discussion 1221–1223.
 54. Alazzaz A, Thornton J, Aletich VA, et al. Intracranial percutaneous transluminal angioplasty for arteriosclerotic stenosis. *Arch Neurol* 2000;57:1625–1630.
 55. Nahser HC, Henkes H, Weber W, et al. Intracranial vertebrobasilar stenosis: angioplasty and follow-up. *AJNR* 2000;21:1293–1301.
 56. Rasmussen PA, Perl J 2nd, Barr JD, et al. Stent-assisted angioplasty of intracranial vertebrobasilar atherosclerosis: an initial experience. *J Neurosurg* 2000;92:771–778.
 57. Connors JJ 3rd, Wojak JC. Percutaneous transluminal angioplasty for intracranial atherosclerotic lesions: evolution of technique and short-term results. *J Neurosurg* 1999;91:415–423.
 58. Marks MP, Marcellus M, Norbash AM, et al. Outcome of angioplasty for atherosclerotic intracranial stenosis. *Stroke* 1999;30:1065–1069.
 59. Callahan AS 3rd, Berger BL. Balloon angioplasty of intracranial arteries for stroke prevention. *J Neuroimaging* 1997;7:232–235.
 60. Singh V, Gress DR, Higashida RT, et al. The learning curve for coil embolization of unruptured intracranial aneurysms. *AJNR* 2002;23:768–771.
 61. Murayama Y, Nien YL, Duckwiler G, et al. Guglielmi detachable coil embolization of cerebral aneurysms: 11 years' experience. *J Neurosurg* 2003;98:959–966.
 62. Lozier AP, Connolly ES Jr., Lavine SD, Solomon RA. Guglielmi detachable coil embolization of posterior circulation aneurysms: a systematic review of the literature. *Stroke* 2002;33:2509–2518.
 63. Malek AM, Halbach VV, Phatouros CC, et al. Balloon-assist technique for endovascular coil embolization of geometrically difficult intracranial aneurysms. *Neurosurgery* 2000;46:1397–1406; discussion 1406–1407.
 64. Vinuela F, Duckwiler G, Mawad M. Guglielmi detachable coil embolization of acute intracranial aneurysm: Perioperative anatomical and clinical outcome in 403 patients. *J Neurosurg* 1997;86:475–482.
 65. Soeda A, Sakai N, Sakai H, et al. Thromboembolic events associated with Guglielmi detachable coil embolization of asymptomatic cerebral aneurysms: evaluation of 66 consecutive cases with use of diffusion-weighted MR imaging. *AJNR* 2003;24:127–132.
 66. Armbruster JS. Accreditation of residency training in the US. *Postgrad Med J* 1996;72:391–394.
 67. Redman HC. The route to subspecialty accreditation. *Radiology* 1989;172:893–894.
 68. Langsley DG. What is the American Board of Medical Specialties? *Pathologist* 1985;39:30–32.
 69. Fader T, Gunzburger LK, Hartmann J, et al. Implementing meaningful CME as an essential component in a community hospital quality assurance plan. *J Contin Educ Health Prof* 1988;8:231–237.
 70. Cleves MA, Weiner JP, Cohen W, et al. Assessing HCFA's Health Care Quality Improvement Program. *Jt Comm J Qual Improv* 1997;23:550–560.
 71. Kremer BK. Physician recertification and outcomes assessment. *Eval Health Prof* 1991;14:187–200.
 72. Pelletier LR, Tackett S. The Performance Measurement Coordinating Council: a town meeting. *J Healthc Qual* 2000;22:24–31.
 73. Hernandez AM. Trends in healthcare practitioner credentialing. *J Health Care Finance* 1998;24:66–70.
 74. Skolnick AA. JCAHO, NCQA, and AMAP establish council to coordinate health care performance measurement. *JAMA* 1998;279:1769–1770.
 75. Alberts MJ, Hademenos G, Latchaw RE, et al. Recommendations for the establishment of Primary Stroke Centers. *JAMA* 2000;283:3102–3109.
 76. Standards of Practice Committee of the Society of Cardiovascular and Interventional Radiology. Angioplasty standard of practice. *J Vasc Intervent Radiol* 1992;3:269–271.
 77. Cooperative Study between the ASNR, ASITN, and SCVIR. Quality improvement guidelines for adult diagnostic neuroangiography. *AJNR* 2000;21:146–150.

78. Levin DC, Becker GJ, Dorros, et al. Training standards for physicians performing peripheral angioplasty and other percutaneous peripheral vascular interventions. A statement for Health Professionals from the Special Group of Councils on Cardiovascular Radiology, Cardio-Thoracic and Vascular Surgery, and Clinical Cardiology, the American Heart Association. *Circulation* 1992;86:1348–1350.
79. Spittell JA, Nanda NC, Creager MA, et al. Recommendations for peripheral transluminal angioplasty: training and facilities. *J Am Coll Cardiol* 1993;21:546–548.
80. White RA. Endovascular credentialing. *Endovascular Surgery Credentialing and Training Subcommittee. J Vasc Intervent Radiol* 1995;6:287–289.
81. Standards of Practice Committee of the Society of Cardiovascular and Interventional Radiology. Standard for diagnostic arteriography in adults. *J Vasc Intervent Radiol* 1993;4:385–395.
82. Standard for the performance of diagnostic cervicocerebral angiography in adults. Res. 5–1999. American College of Radiology Standards 2000–2001. Reston VA: American College of Radiology, 2000, pp. 415–426.
83. Pepine CJ, Allen HD, Bashore TM, et al. Guidelines for cardiac catheterization and cardiac catheterization laboratories. *J Am Coll Cardiol* 1991;18:1149–1182.
84. Training Program Standards Committee. Standards for training in cardiac catheterization and angiography. *Cathet Cardiovasc Diagn* 1980;6:345–348.
85. Friesinger GC, Adams DF, Bourassa MG, et al. Optimal resources for examination of the heart and lungs: cardiac catheterization and radiographic facilities. *Circulation* 1983;68:893–930A.
86. Conti CR, Faxon DP, Gruentzig AR, et al. 17th Bethesda Conference: adult cardiology training. Task Force III: training in cardiac catheterization. *J Am Coll Cardiol* 1986;7:1205–1206.
87. Hodgson JM, Tommaso CL, Watson RM, et al. Core curriculum for the training of adult invasive cardiologists: Report of the Society for Cardiac Angiography and Interventions Committee on Training Standards. *Cath Cardiovasc Diagn* 1996;37:392–408.
88. Hirshfeld JW Jr, Ellis SG, Faxon DP, et al. Recommendations for the assessment and maintenance of proficiency in coronary interventional procedures. Statement of the American College of Cardiology. *J Am Coll Cardiol* 1998;31:722–743.
89. Ryan TJ, Bauman WB, Kennedy JW, et al. Guidelines for percutaneous transluminal coronary angioplasty. *J Am Coll Cardiol* 1993;22:2033–2054.
90. Weaver WF, Myler RK, Sheldon WC, et al. Guidelines for physician performance of percutaneous transluminal coronary angioplasty. *Cathet Cardiovasc Diagn* 1985;11:109–112.
91. William DO, Gruentzig A, Kent KM, et al. Guidelines for the performance of percutaneous transluminal coronary angioplasty. *Circulation* 1982;66:693–694.
92. Ryan TJ, Faxon DP, Gunnar RM, et al. Guidelines for percutaneous transluminal coronary angioplasty. *J Am Coll Cardiol* 1988;12:529–545.
93. Cowley MJ, King SB III, Baim D, et al. Guidelines for credentialing and facilities for performance of coronary angioplasty. *Cathet Cardiovasc Diagn* 1988;15:136–138.
94. Ryan TJ, Klocke FJ, Reynolds WA. Clinical competence in percutaneous transluminal coronary angioplasty. *Circulation* 1990;81:2041–2046.
95. Gomez CR, Kinkel P, Masdeu JC, et al. American Academy of Neurology guidelines for credentialing in neuroimaging. Report from the task force on updating guidelines for credentialing in neuroimaging. *Neurology* 1997;49:1734–1737.
96. Bakshi R, Alexandrov AV, Gomez CR, Masdeu JC. Neuroimaging curriculum for neurology trainees: Report from the Neuroimaging Section of the AAN. *J Neuroimaging* 2003;13:215–217.
97. Higashida RT, Hopkins LN, Berenstein A, et al. Program requirements for residency/fellowship education in neuroendovascular surgery/interventional Neuroradiology: a Special Report on Graduate Medical Education. *AJNR* 2000;21:1153–1159.
98. White RA, Hodgson KJ, Ahn SS, et al. Endovascular interventions training and credentialing for vascular surgeons. *J Vasc Surg* 1999;29:177–186.
99. American Board of Internal Medicine Committee on Interventional Cardiology. Certificate of Added Qualifications in Interventional Cardiology. [ABIM Web site]. Available at: www.abim.org/subspec/ic.htm. Accessed October 8, 2004.
100. American Board of Radiology. Certificate in Diagnostic Radiology. [American Board of Radiology Web site]. 2004. Available at: www.theabr.org/DRAppandFeesinFrame.htm. Accessed October 8, 2004.
101. ACGME. Program Requirements for Residency Education in Neuroradiology. [ACGME Web site]. Available at: www.acgme.org/downloads/RRC_progReq/423pr602.pdf. Accessed October 8, 2004.
102. ACGME. Program Requirements for Residency Education in Vascular Neurology. [ACGME Web site]. Available at: www.acgme.org/downloads/RRC_progReq/188pr202.pdf. Accessed October 8, 2004.
103. ACGME. Program Requirements for Residency Education in Endovascular Surgical Neuroradiology [ACGME Web site]. Available at: www.acgme.org/downloads/RRC_progReq/422pr403.pdf. Accessed October 8, 2004.
104. ACGME. Program Requirements for Graduate Medical Education in Diagnostic Radiology [ACGME Web site]. Available at: www.acgme.org/downloads/RRC_progReq/420pr703_u804.pdf. Accessed October 8, 2004.
105. Murray WB, Good ML, Gravenstein JS, et al. Learning about new anesthetics using a model driven, full human simulator. *J Clin Monit Comput* 2002;17:293–300.
106. Schwid HA, Rooke GA, Carline J, et al. Evaluation of anesthesia residents using mannequin-based simulation: a multiinstitutional study. *Anesthesiology* 2002;97:1434–1444.
107. Watterson JD, Beiko DT, Kuan JK, Denstedt JD. Randomized prospective blinded study validating acquisition of ureteroscopy skills using computer based virtual reality endourological simulator. *J Urol* 2002;168:1928–1932.
108. Rowe R, Cohen RA. An evaluation of a virtual reality airway simulator. *Anesth Analg* 2002;95:62–66.
109. Forrest FC, Taylor MA, Postlethwaite K, Aspinall R. Use of a high-fidelity simulator to develop testing of the technical performance of novice anaesthetists. *Br J Anaesth* 2002;88:338–344.
110. Byrne AJ, Greaves JD. Assessment instruments used during anaesthetic simulation: review of published studies. *Br J Anaesth* 2001;86:445–450.
111. Issenberg SB, McGaghie WC, Hart IR, et al. Simulation technology for health care professional skills training and assessment. *JAMA* 1999;282:861–866.
112. Riley RH, Wilks DH, Freeman JA. Anaesthetists' attitudes towards an anaesthesia simulator. A comparative survey: USA and Australia. *Anaesth Intensive Care* 1997;25:514–519.
113. Barr JD, Connors JJ, Sacks D, et al. Quality Improvement Guidelines for the Performance of Cervical Carotid Angioplasty and Stent Placement. *J Vasc Interv Rad* 2003;14:1079–1093.
114. McGrath PD, Wennberg DE, Dickens JD Jr., et al. Relation between operator and hospital volume and outcomes following percutaneous coronary interventions in the era of the coronary stent. *JAMA* 2000;284:3139–3144.
115. Wennberg DE, Lucas FL, Birkmeyer JD, Bredenberg CE, Fisher ES. Variation in carotid endarterectomy mortality in the Medicare population: trial hospitals, volume, and patient characteristics. *JAMA* 1998;279:1278–1281.
116. Hannan EL, Wu C, Ryan TJ, et al. Do hospitals and surgeons with higher coronary artery bypass graft surgery volumes still have lower risk-adjusted mortality rates? *Circulation* 2003;108:795–801.

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