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RESOLUTION NO. 30

BE IT RESOLVED,

**that the American College of Radiology adopt the ACR–
AIUM–SPR–SRU Practice Guideline for the Performance of
Transcranial Doppler Ultrasound**

Sponsored By: ACR Council Steering Committee

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ACR–AIUM–SPR–SRU PRACTICE GUIDELINE FOR THE PERFORMANCE OF TRANSCRANIAL DOPPLER ULTRASOUND

PREAMBLE

These guidelines are an educational tool designed to assist practitioners in providing appropriate radiologic care for patients. They are not inflexible rules or requirements of practice and are not intended, nor should they be used, to establish a legal standard of care. For these reasons and those set forth below, the American College of Radiology cautions against the use of these guidelines in litigation in which the clinical decisions of a practitioner are called into question.

The ultimate judgment regarding the propriety of any specific procedure or course of action must be made by the physician or medical physicist in light of all the circumstances presented. Thus, an approach that differs from the guidelines, standing alone, does not necessarily imply that the approach was below the standard of care. To the contrary, a conscientious practitioner may responsibly adopt a course of action different from that set forth in the guidelines when, in the reasonable judgment of the practitioner, such course of action is indicated by the condition of the patient, limitations of available resources, or advances in knowledge or technology subsequent to publication of the guidelines. However, a practitioner who employs an approach substantially

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different from these guidelines is advised to document in the patient record information sufficient to explain the approach taken.

The practice of medicine involves not only the science, but also the art of dealing with the prevention, diagnosis, alleviation, and treatment of disease. The variety and complexity of human conditions make it impossible to always reach the most appropriate diagnosis or to predict with certainty a particular response to treatment. Therefore, it should be recognized that adherence to these guidelines will not assure an accurate diagnosis or a successful outcome. All that should be expected is that the practitioner will follow a reasonable course of action based on current knowledge, available resources, and the needs of the patient to deliver effective and safe medical care. The sole purpose of these guidelines is to assist practitioners in achieving this objective.

I. INTRODUCTION

The clinical aspects contained in specific sections of this guideline (Introduction, Indications, Specifications of the Examination, and Equipment Specifications) were developed collaboratively by the American College of Radiology (ACR), the American Institute of Ultrasound in Medicine (AIUM), the Society for Pediatric Radiology (SPR), and the Society of Radiologists in Ultrasound (SRU). Recommendations for physician requirements, written request for the examination, procedure documentation, and quality control vary ~~between~~ **among** the ~~two~~ organizations and are addressed by each separately.

Transcranial Doppler Ultrasound (**TCD**) is a noninvasive technique that assesses blood flow within the circle of Willis and the vertebrobasilar system. ~~in children who have a closed anterior fontanelle, and in adults~~

II. INDICATIONS

A. Indications for a transcranial Doppler ultrasound examination of adults include, but are not limited to:

1. Detection **and follow-up** of stenosis or occlusion in a major intracranial artery in the circle of Willis and vertebrobasilar system, including monitoring of thrombolytic therapy for acute stroke patients [1-3].
- ~~2. Follow up of patients with known stenosis or occlusion of a major intracranial artery in the circle of Willis and vertebrobasilar system~~
2. **Detection of cerebral vasculopathy [4-5].**
3. Detection and monitoring of vasospasm in patients with **spontaneous or traumatic** subarachnoid hemorrhage [2,6].
4. **Evaluation of collateral pathways of intracranial blood flow, including after intervention [7].**
5. Detection of circulating **cerebral microemboli [3].** ~~emboli or intracranial Willis and vertebrobasilar system~~
6. Detection of right-to-left shunts [2,8]. ~~using agitated saline injection~~
7. Assessment of **cerebral** vasomotor reactivity [2-3].

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- 33 8. **Adjunct in the** confirmation of the clinical diagnosis of brain death [2-3,9]
34 [4,10]. ~~by detection of complete cerebral circulatory arrest~~
- 35 9. Intraoperative and periprocedural monitoring to detect **cerebral** embolization,
36 thrombosis, hypoperfusion, and hyperperfusion [2,11].
- 37 **10. Evaluation of sickle cell disease to determine stroke risk [12-17].**
- 38 **11. Assessment of arteriovenous malformations [4].**
- 39 **12. Detection and follow-up of intracranial aneurysms.**
- 40 **13. Evaluation of positional vertigo or syncope [18].**

41 42 **B. Additional applications in children include, but are not limited to:**

- 43 **1. Assessment of intracranial pressure and hydrocephalus [19-20].**
- 44 **2. Assessment of hypoxic ischemic encephalopathy [4-5].**
- 45 **3. Assessment of dural venous sinus patency [4-5].**

46 47 ~~B. Children~~

- 48 ~~1. Evaluation of stenosis or occlusion in the circle of Willis and vertebrobasilar~~
49 ~~system in patients with sickle cell anemia to determine the need for and~~
50 ~~continuation of blood transfusions~~
- 51 ~~2. Follow up of patients with known stenosis or occlusion of an artery in the circle~~
52 ~~of Willis and vertebrobasilar system in patients with sickle cell anemia~~
- 53 ~~3. Detection of vasculopathy, such as moyamoya~~
- 54 ~~4. Assessment of arteriovenous malformations~~
- 55 ~~5. Confirmation of the clinical diagnosis of brain death, by detection of complete~~
56 ~~cerebral circulatory arrest in infants more than 6 months of age~~

57 58 **III. QUALIFICATIONS AND RESPONSIBILITIES OF THE PHYSICIAN**

59
60 *Each organization will address this section in its document.*

61
62 See the ACR-SPR-SRU Practice Guideline for Performing and Interpreting Diagnostic
63 Ultrasound Examinations.

64 65 **IV. WRITTEN REQUEST FOR THE EXAMINATION**

66
67 *Each organization will address this section in its document.*

68
69 The written or electronic request for transcranial Doppler ultrasound
70 should provide sufficient information to demonstrate the medical necessity
71 of the examination and allow for its proper performance and
72 interpretation.

73
74 Documentation that satisfies medical necessity includes 1) signs and
75 symptoms and/or 2) relevant history (including known diagnoses).
76 Additional information regarding the specific reason for the examination
77 or a provisional diagnosis would be helpful and may at times be needed to
78 allow for the proper performance and interpretation of the examination.

79 The request for the examination must be originated by a physician or other
80 appropriately licensed health care provider. The accompanying clinical
81 information should be provided by a physician or other appropriately
82 licensed health care provider familiar with the patient's clinical problem or
83 question and consistent with the state scope of practice requirements.
84 (ACR Resolution 35, adopted in 2006)

85
86 **V. SPECIFICATIONS OF THE EXAMINATION**

87
88 **Cerebral blood flow velocities and resistive index (RI) can be variable and are**
89 **affected by age, the arterial carbon dioxide level, and cerebral and systemic**
90 **perfusion, and thus are influenced by the state of patient arousal, the effect of**
91 **mechanical ventilation and suctioning, and the presence of systemic shunts, cardiac**
92 **disease, current fever, or anemia. It is important to perform examinations when**
93 **patients (especially children) are awake, quiet, and calm. If possible, examinations**
94 **should not be performed if the patient has been sedated or anesthetized earlier the**
95 **same day.**

96
97 **A. Infants with Open Fontanelle**

98
99 **Depending on the size of the child, sector, curvilinear, or linear transducers with**
100 **Grayscale and Doppler frequencies from 5 MHz to 10 MHz should be used. Duplex**
101 **ultrasound is preferred over nonimaging Doppler methods for more precise**
102 **localization and insonation within the targeted vessels when imaging through the**
103 **fontanelles.**

104
105 **In infants, open fontanelles provide acoustic windows to the intracranial circulation.**
106 **The internal carotid vessels and the branches of the circle of Willis can be**
107 **interrogated through the anterior fontanelle in coronal and sagittal planes (although**
108 **the middle cerebral artery may be better interrogated via a transtemporal**
109 **approach; see below) [4]. For basic assessment of global cerebral arterial flow and**
110 **waveform analysis, interrogation of the pericallosal branch of the anterior cerebral**
111 **artery on sagittal imaging via the anterior fontanelle is the simplest, most reliable**
112 **approach. The superior sagittal sinus can be evaluated through an open sagittal**
113 **suture. Imaging of the posterior circulation can be performed via the foramen**
114 **magnum or via the posterolateral fontanelle located just posterior to the mastoid**
115 **process [21-22].**

116
117 **When assessing for elevated intracranial pressure, interrogation of the pericallosal**
118 **branch of the anterior cerebral artery both before and after gentle compression of**
119 **the anterior fontanelles, can be performed [23-24]. Care should be taken to**
120 **minimize the degree and duration of compression.**

123 **B. Adults and Children after Fontanelle Closure**

124

125 Either **transcranial spectral Doppler, power M-mode Doppler, or grayscale, color, and**
126 ~~spectral Doppler ultrasound (transcranial duplex)~~ **transcranial color-coded duplex**
127 **sonography (TCCS) should be performed with the patient supine. in the supine position**
128 **If velocity reference standards have been previously acquired with nonimaging TCD**
129 **methods (and thus not angle-corrected), velocity measurements with imaging**
130 **methods (TCCS) should not be angle corrected to allow comparison with reference**
131 **values [5,25]. It should be noted that velocities obtained with duplex imaging**
132 **equipment may be lower than those obtained with nonduplex imaging equipment.**
133 **Therefore, stroke-risk cutpoints obtained with imaging equipment may need to be**
134 **lowered [26-28]. However, if validated reference values for angle corrected TCCS**
135 **velocities exist in an ultrasound laboratory and a sufficient length of vessel is**
136 **visualized during TCCS to allow angle correction, and then angle corrected**
137 **velocities can be obtained [29].**

138

139 **In adults, transcranial Doppler requires the use of lower frequency transducers to**
140 **adequately penetrate the calvarium to produce useful Grayscale images and**
141 **Doppler signals. A 2 to 3 MHz transducer or multifrequency transducer with 2 to 3**
142 **MHz spectral Doppler capability is commonly required [4]. For children or small**
143 **adults, adequate imaging may be possible at higher frequencies.**

144

145 **Representative views should be obtained of each the distal internal carotid arteries,**
146 **anterior, middle, and posterior cerebral artery arteries in the circle of Willis, and of the**
147 **vertebrobasilar system. Any abnormalities should be evaluated and documented.**
148 **Both the left and right sides of the circulation should be interrogated, unless the**
149 **examination is performed to followup a known abnormality of a specific vessel.**
150 ~~should be obtained, including documentation of pathology. Two windows can be used~~
151 ~~after closure of the anterior fontanelle to examine the intracranial vessels: the temporal~~
152 ~~bone and the foramen magnum. The transtemporal window is the area on the temporal~~
153 ~~bone cephalad to the zygomatic arch and anterior to the ear. On grayscale images, the~~
154 ~~hypoechoic heart-shaped cerebral peduncles and echogenic star-shaped basilar cistern are~~
155 ~~the reference landmarks~~

156

157 **After fontanelle closure, the two available acoustic windows are the temporal bone**
158 **and the foramen magnum. The transtemporal window is the thinnest portion of the**
159 **temporal bone (the pterion) located cephalad to the zygomatic arch and anterior to**
160 **the ear (Figure 1).**

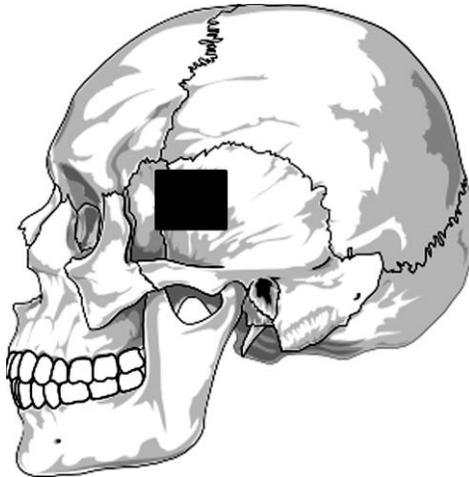
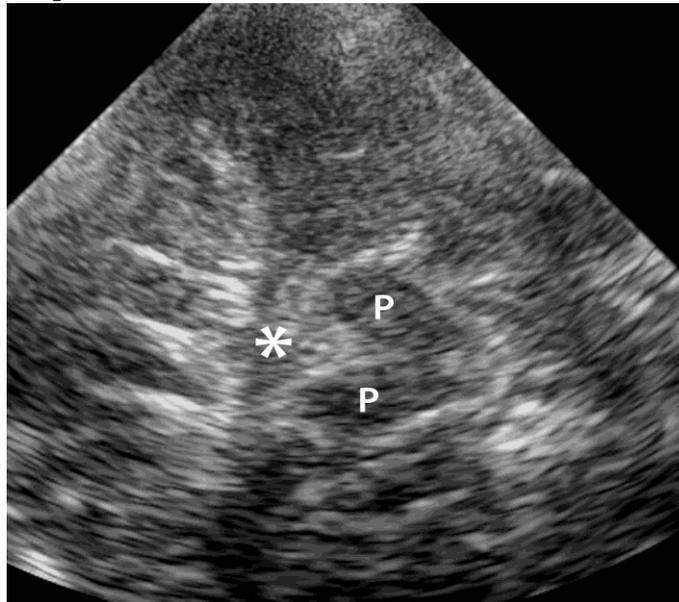


Figure. 1 – Location of the pterion.

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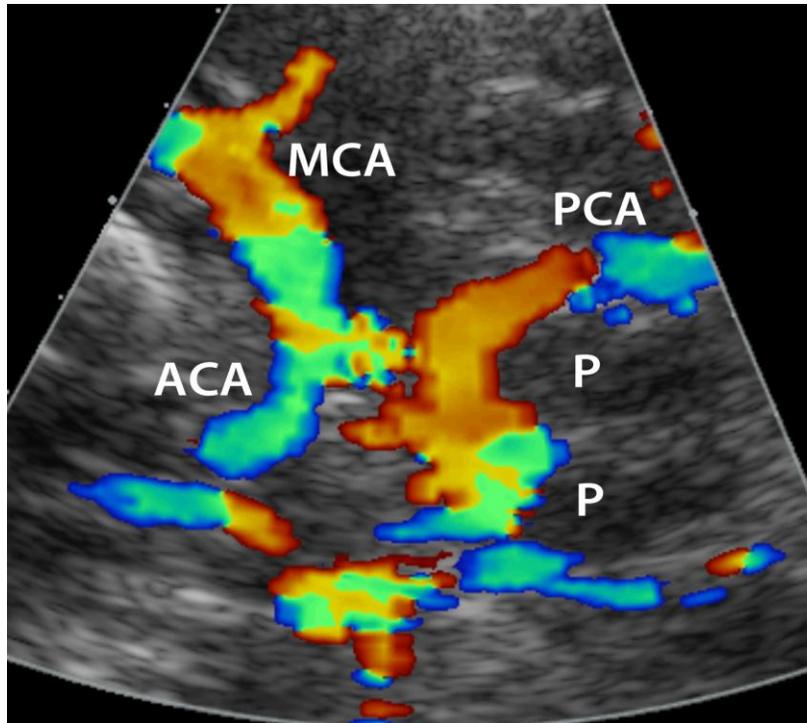
On Grayscale images, the hypoechoic heart-shaped cerebral peduncles and echogenic star-shaped basilar cistern are the reference landmarks for the circle of Willis (Fig. 2) [30-31].



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Figure 2 – Transtemporal Grayscale image showing the cerebral peduncles (P) with the echogenic basilar cistern (*) located just anteriorly.

Anterior **and lateral** to the cistern is the middle cerebral artery, which should be insonated **using** with Doppler ultrasound, including color and spectral Doppler (Fig. 3) [4].



174

175

176 **Figure 3 – Transtemporal color Doppler image of the circle of Willis showing the**
 177 **middle cerebral artery (MCA) with flow directed toward the transducer. The**
 178 **anterior cerebral artery (ACA) flow is directed away from the transducer. The**
 179 **posterior cerebral artery (PCA) is seen coursing around the cerebral peduncles (P).**
 180 ~~analysis. With a 2 MHz transducer or multifrequency transducer with 2 MHz spectral~~
 181 ~~Doppler, the~~

182

183 **Depending on the clinical indication, the middle cerebral artery should be interrogated**
 184 **at 2 to 5 mm intervals from its most superficial point below the calvarium to the**
 185 **bifurcation of the A1 segment the A1 segment of the ACA and the M1 segment of the**
 186 **MCA [32]. Flow in the MCA is directed towards the transducer. and The anterior**
 187 **cerebral artery should be interrogated distal to the bifurcation. studied as far medially**
 188 **as possible Flow in the ACA should be away from the transducer (Fig. 3). The**
 189 **posterior cerebral artery PCA is found located immediately anterior to the heart-shaped**
 190 **cerebral peduncles and has forward flow toward the transducer in the P1 segment while**
 191 **flow in the more distal P2 segment is directed away from the probe. After completing**
 192 **insonation of the right sided vessels, repeat the imaging planes on the left side**

193

194 The foramen magnum can be used to study the vertebral and basilar arteries. The patient
 195 should be turned to one side and the neck ~~should be~~ flexed so that the chin touches the
 196 chest. ~~A 2-MHz~~ The transducer is placed over the upper neck at the base of the skull and
 197 angled **cephalad** through the foramen of magnum towards the nose [31]. **For imaging**
 198 **Doppler studies,** the reference landmark is the hypoechoic medulla. ~~or bridge of the nose~~
 199 ~~for nonimaging transducers~~ The vertebral arteries should be interrogated at 2 to 5 mm
 200 intervals. On ~~color Doppler ultrasound~~ **TCCS,** the vertebral arteries have a V-shaped
 201 configuration as they extend superiorly to form the basilar artery. Flow in the vertebral

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202 and basilar arteries is directed away from the transducer and should be interrogated up to
203 the distal end of the basilar artery.

204
205 In patients with suspected carotid stenosis or occlusion, a transorbital examination of the
206 ophthalmic arteries and carotid siphons can be performed [33-34]. **These images must**
207 **be performed at reduced power settings with a mechanical index (MI) not to exceed**
208 **0.23 in order to prevent ocular injury [35].** ~~at reduced emitting power levels (10% or~~
209 ~~17 mW)~~

210
211 In patients with subarachnoid hemorrhage and signs of vasospasm, a submandibular
212 approach can be used to sample the distal internal carotid artery in the neck to calculate
213 mean flow velocity ratios between the middle cerebral and internal carotid arteries, ~~also~~
214 ~~known as the so-called hemispheric or Lindegaard index [36].~~ **Both approaches are**
215 **performed with 2 MHz spectral Doppler without angle correction.** ~~Both approaches~~
216 ~~are performed with 2 MHz spectral Doppler without angle correction~~

217
218 **Doppler waveform analysis of the cerebral arteries should be performed. In children**
219 **with sickle cell disease, this analysis should include** ~~including~~ the time averaged mean
220 maximum **mean** velocity ~~in children with sickle cell disease~~ according to the STOP trial
221 criteria [4,14-17]. In adults, either mean flow velocity or peak systolic velocity ~~with and~~
222 **pulsatility (PI) or resistive indexes (RI) should be recorded.** The velocity is obtained at 2
223 to 5 mm intervals along the entire course of the vessel. Velocity can be measured either
224 by ~~the an~~ automatic tracing method or by **manual placement of cursors.** ~~performing a~~
225 ~~manual tracing~~

226
227 ~~Angle correction should not be used~~ **Angle-corrected TCCS velocities have typically**
228 **not been used for studies such as pediatric sickle cell evaluation, but this technique**
229 **has been recommended for some studies such as adult stroke evaluation if TCCS**
230 **angle corrected reference values are validated for a specific group of patients**
231 **[5,25,29,37]. The use of angle correction thus depends upon the clinical information**
232 **needed and the reference standards used in clinical decision making. The written**
233 **report should indicate whether or not angle correction was used.**

234

235 VI. DOCUMENTATION

236

237 *Each organization will address this section in its document.*

238

239 Adequate documentation is essential for high-quality patient care. There should be a
240 permanent record of the ultrasound examination and its interpretation. Comparison with
241 prior relevant imaging studies may prove helpful. Images of all appropriate areas, both
242 normal and abnormal, should be recorded. Variations from normal size should generally
243 be accompanied by measurements. ~~Images should be labeled with the patient~~
244 ~~identification, facility identification, examination date, image orientation and vessel~~
245 ~~labeling~~ **The initials of the operator should be accessible on the images or**
246 **electronically on PACS. Images should be labeled with the patient identification,**
247 **facility identification, examination date, and image orientation.** An official

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248 interpretation (final report) of the ultrasound examination should be included in the
249 patient's medical record. Retention of the ultrasound examination images should be
250 ~~consistent both with~~ **based on** clinical need and ~~with~~ relevant legal and local health care
251 facility requirements.

252

253 Reporting should be in accordance with the ACR Practice Guideline for Communication
254 of Diagnostic Imaging Findings.

255

256 **VII. EQUIPMENT SPECIFICATIONS**

257

258 Transcranial Doppler should be performed with a real-time **imaging** scanner with
259 Doppler capability, using a ~~2-to-4~~ **1 to 5** MHz transducer that can penetrate the temporal
260 bone and foramen magnum, or a nonimaging Doppler instrument (**TCD or power M-**
261 **mode Doppler**) with 2 MHz pulsed Doppler capability. Doppler images and/or data are
262 obtained at 2 mm **to 5 mm** intervals with a **3 mm to 6 mm** gate. ~~4-to-6 mm (larger steps~~
263 ~~such as 5 mm are allowed for 10 to 15 mm gates)~~ Color or spectral Doppler should be
264 used to locate the intracranial vessels in all cases. The color gain settings should be
265 maximized so that a well defined ~~flow jet~~ **vessel** is displayed. The Doppler setting should
266 be adjusted to obtain the highest velocity in all cases. Doppler power output should be as
267 low as reasonably achievable.

268

269 **VIII. QUALITY CONTROL AND IMPROVEMENT, SAFETY, INFECTION** 270 **CONTROL, AND PATIENT EDUCATION**

271

272 *Each organization will address this section in its document.*

273

274 Policies and procedures related to quality, patient education, infection control, and safety
275 should be developed and implemented in accordance with the ACR Policy on Quality
276 Control and Improvement, Safety, Infection Control, and Patient Education appearing
277 under the heading *Position Statement on QC & Improvement, Safety, Infection Control,*
278 *and Patient Education* on the ACR web site (<http://www.acr.org/guidelines>).

279

280 Equipment performance monitoring should be in accordance with the ACR Technical
281 Standard for Diagnostic Medical Physics Performance Monitoring of Real Time
282 Ultrasound Equipment.

283

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285

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287 *Process for Developing ACR Practice Guidelines and Technical Standards* on the ACR
288 web site (<http://www.acr.org/guidelines>) by the Guidelines and Standards Committees of
289 the Commissions on Ultrasound and Pediatric Radiology in collaboration with the AIUM,
290 the SPR, and the SRU.

291

292 Collaborative Committee – members represent their societies in the initial and final
293 revision of this guideline

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294 ACR

295 Brian D. Coley, MD, Chair
296 Lynn A. Fordham, MD
297 Beverly E. Hashimoto, MD, FACR
298 Marta Hernanz-Schulman, MD, FACR
299 Carol M. Rumack, MD, FACR

AIUM

Harris L. Cohen, MD, FACR
Mary E. McCarville, MD
Tatjana Rundek, MD, PhD

301 SPR

302 Els Nijs, MD
303 Martha M. Munden, MD
304 Cicero T. Silva, MD

SRU

Dorothy I. Bulas, MD, FACR
Harriet J. Paltiel, MD
Susan L. Voci, MD

306 ACR Guidelines and Standards Committee – Ultrasound – ACR Committee responsible
307 for sponsoring the draft through the process.

308
309 Mary C. Frates, MD, FACR, Chair
310 Beverly E. Hashimoto, MD, FACR, Vice-Chair
311 Sandra O. DeJesus Allison, MD
312 Marcela Bohm-Velez, MD, FACR
313 Helena Gabriel, MD
314 Ruth B. Goldstein, MD
315 Robert D. Harris, MD, MPH, FACR
316 Leann E. Linam, MD
317 Maitray D. Patel, MD
318 Henrietta K. Rosenberg, MD, FACR
319 Sheila Sheth, MD, FACR
320 Robert M. Sinow, MD
321 Maryellen R.M. Sun, MD
322 Sharlene A. Teefey, MD, FACR
323 Jason M. Wagner, MD
324 Deborah Levine, MD, FACR, Chair, Commission

326 ACR Guidelines and Standards Committee – Pediatric – ACR Committee responsible for
327 sponsoring the draft through the process.

328
329 Marta Hernanz-Schulman, MD, FACR, Chair
330 Sara J. Abramson, MD, FACR
331 Brian D. Coley, MD
332 Kristin L. Crisci, MD
333 Eric N. Faerber, MD, FACR
334 Kate A. Feinstein, MD, FACR
335 Lynn A. Fordham, MD
336 S. Bruce Greenberg, MD
337 J. Herman Kan, MD
338 Beverly Newman, MD, MB, BCh, BSC, FACR
339 Marguerite T. Parisi, MD, MS

340 Sumit Pruthi, MBBS
341 Nancy K. Rollins, MD
342 Manrita K. Sidhu, MD
343 Donald Frush, MD, FACR, Chair, Commission
344

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500 standards published before 1999, the effective date was January 1 following the year in
501 which the guideline or standard was amended, revised, or approved by the ACR Council.

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