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# Common Data Elements for Radiological Imaging of Patients with Subarachnoid Hemorrhage: Proposal of a Multidisciplinary Research Group

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## Abstract

**Introduction:** Lack of homogeneous definitions for imaging data and consensus on their relevance in the setting of subarachnoid hemorrhage and unruptured intracranial aneurysms lead to a difficulty of data pooling and lack of robust data. The aim of the National Institute of Health/National Institute of Neurological Disorders and Stroke, Unruptured Intracranial Aneurysm (UIA) and Subarachnoid Hemorrhage (SAH) Common Data Elements (CDE) Project was to standardize data elements to ultimately facilitate data pooling and establish a more robust data quality in future neurovascular research on UIA and SAH.

**Methods:** For the subcommittee 'Radiological imaging of SAH,' international cerebrovascular specialists with imaging expertise in the setting of SAH were selected by the steering committee. CDEs were developed after reviewing the literature on neuroradiology and already existing CDEs for other neurological diseases. For prioritization, the CDEs were classified into 'Core,' 'Supplemental—Highly Recommended,' 'Supplemental' and 'Exploratory.'

**Results:** The subcommittee compiled 136 CDEs, 100 out of which were derived from previously established CDEs on ischemic stroke and 36 were newly created. The CDEs were assigned to four main categories (several CDEs were assigned to more than one category): 'Parenchymal imaging' with 42 CDEs, 'Angiography' with 49 CDEs, 'Perfusion imaging' with 20 CDEs, and 'Transcranial doppler' with 55 CDEs. The CDEs were classified into core, supplemental highly recommended, supplemental and exploratory elements. The core CDEs were *imaging modality, imaging modality type, imaging modality vessel, angiography type, vessel angiography arterial anatomic site and imaging vessel angiography arterial result*.

**Conclusions:** The CDEs were established based on the current literature and consensus across cerebrovascular specialists. The use of these CDEs will facilitate standardization and aggregation of imaging data in the setting of SAH. However, the CDEs may require reevaluation and periodic adjustment based on current research and improved imaging quality and novel modalities.

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## Introduction

The National Institute of Neurological Disorders and Stroke (NINDS) began an effort to standardize and harmonize data collection in 2006. The goal of this project was to standardize naming, data definitions, data structure, and response options for variables used in NINDS-funded research [1]. A NINDS effort to develop common data elements (CDEs) for stroke research was launched in 2011 [2]. Eight working groups (WGs) were created, including one focused on imaging. Stroke-related CDEs have been curated and updated by a standing group on an annual basis.

The NINDS Stroke CDEs initially focused on ischemic stroke trials. Many of the variables important for research on unruptured intracranial aneurysms (UIA) and subarachnoid hemorrhage (SAH) were not included. The purpose of this project was to develop a menu of data names, definitions, and response options for investigators designing trials for SAH prevention, treatment, or recovery. Use of these CDEs will facilitate communication and progress in our field.

The focus of this WG was to develop CDEs for imaging. These include vascular imaging of intracranial aneurysms and large artery vasospasm, parenchymal imaging to define SAH and infarction, and perfusion imaging to define perfusion abnormalities, among others.

Many variables, such as imaging modality for example, have been defined previously by the NINDS Stroke project, and these imaging modalities were carried forward to ensure ease of use and communication.

## Methods

The UIA and SAH CDE project is described by Suarez et al. [3] The Steering Committee for the UIA and SAH CDE project identified individuals with expertise in cerebrovascular disease and imaging and assigned two co-chairs (NE and CD). Individuals were tasked with identifying from the existing NINDS Stroke CDEs or developing new CDEs for the following nine separate imaging domains (Fig. 1).

The topics and the responsible WG members were:

- Computerized tomography (CT)/CT-Angiography/CT-Perfusion (MW)
- Transcranial doppler sonography (KH)
- Digital subtraction angiography (PM)
- Magnetic resonance (MR) imaging/MR-Angiography (MW)
- Aneurysm morphology (NE, DR)
- Computational fluid dynamics (CFD) (NE)
- SAH grading scales (CD)
- Aneurysm types (TK)

These subcommittees then proposed CDEs, the corresponding definitions as well classification according to relevance for future studies into four groups for the underlying topic to the remaining subcommittee members: (1) Core CDEs—elements which can be consistently collected across studies and which should be employed in studies concerning the corresponding disease or therapeutic area, (2) Supplemental—Highly Recommended CDEs—elements that are essentially based on certain conditions or study types in clinical research studies and that are strongly recommended for the specific disease or therapeutic area,
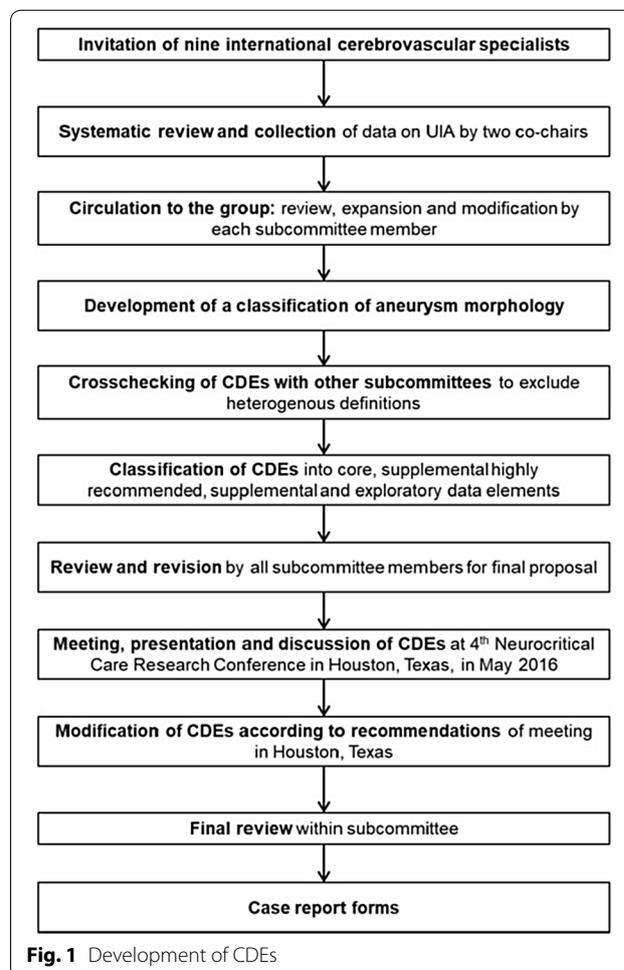


**Fig. 1** Development of CDEs

(3) Supplemental CDEs—elements that are commonly collected in clinical research studies, but whose relevance depends on the study design or type of research and (4) Exploratory CDEs—elements which are reasonable to use, but whose validity is limited due to insufficient availability of data, so they require further validation.

Previously established CDEs from other entities were reviewed, adapted for the UIA and SAH CDE project and proposed to all subcommittee members for review via email. The CDE definitions and categorization were reviewed by the two co-chairs, and after a final round of review and agreement by each subcommittee member, case report forms were developed.

## Imaging Common Data Elements Overview

A total of 136 CDEs on imaging for SAH were developed. These include 97 previously established CDEs from other neurological diseases; three previously established CDEs which were modified for the UIA and SAH CDE project; and 36 new CDEs. Forty-two CDEs were classified to 'Parenchymal imaging,' 49 to 'Angiography,' 20 to 'Perfusion imaging,' and 55 to 'Transcranial doppler.' Each of the CDEs were assigned a specific identification number, a CDE name, variable name, definition, classification, permissible value, a code name, a code description and, if necessary, a unit of measure as well as a question text. If a CDE was assigned to more than one category, it retained its unique identification number. In addition, if the CDE was pulled from the NINDS Stroke CDEs, it retained that identification number. According to the priority in the main category, the CDEs were classified.

### Parenchymal Imaging

Forty of the 42 CDEs in the main category 'Parenchymal imaging' were adopted directly from pre-existing CDEs, one was edited, and one was newly created. Out of the 42 CDEs, *Imaging modality* and *Imaging modality type* were classified as Core (Table 1).

The 21 Supplemental—Highly Recommended CDEs were:

- Imaging study ID number
- Imaging study date and time
- Imaging acquisition reason
- Imaging acquisition reason other text
- Imaging slice thickness value
- Imaging computed tomography angiography source used indicator
- Intraventricular hemorrhage status
- Graeb intraventricular hemorrhage scale—right lateral ventricle score [4]
- Graeb intraventricular hemorrhage scale—left lateral ventricle score

- Graeb intraventricular hemorrhage scale—third ventricle score
- Graeb intraventricular hemorrhage scale—fourth ventricle score
- Graeb intraventricular hemorrhage scale—total score
- Intraventricular hemorrhage volume measurement
- Subarachnoid hemorrhage indicator
- Fisher scale grade [5]
- Modified Fisher scale grade [6]
- Subdural hematoma present indicator
- Subdural hematoma type
- Hydrocephalus present indicator
- Arteriovenous malformation present indicator
- Arteriovenous malformation anatomic site

The remaining Supplemental and/or Exploratory CDEs are listed in Table 1.

### Angiography

The category 'Angiography' comprises 49 CDEs, of which 20 were entirely reutilized, two were previously established modified, and 27 were novel. This category was further divided into the subtopics (A) 'Vascular imaging,' (B) 'Endovascular treatment' and (C) 'CFD: Volumetric factors,' 'CFD: Surface factors' and 'CFD: Hemodynamic factors.' In this category, three CDEs were defined as Core (*Imaging modality vessel imaging angiography type, imaging vessel angiography arterial anatomic site, and imaging vessel angiography arterial result*).

The 15 Supplemental—Highly Recommended CDEs were:

- Imaging study ID number
- Imaging study date and time
- Acquisition reason
- Acquisition reason other text
- Magnetic resonance angiography type
- CT angiography type
- Imaging vessel angiography level of confidence status
- Imaging vessel angiography aneurysm anatomic site
- Imaging aneurysm anatomic site
- Imaging aneurysm dome measurement
- Imaging aneurysm neck measurement
- Imaging unruptured intracranial aneurysm morphology type
- Imaging aneurysm aspect ratio value
- Aneurysm occlusion percentage value
- Aneurysm occlusion Raymond–Roy classification category [7]

The remaining 18 Supplemental and 13 Exploratory elements are listed in Table 2.

**Table 1** CDEs—parenchymal imaging

| CDE ID | CDE name | Definition | Permissible value | Classification |
|---|---|---|---|---|
| C13750 | Imaging study ID number | Unique identification number assigned to the study or assessment session | | Supplemental—highly recommended |
| C02494 | Imaging study date and time | Date (and time, if applicable and known), the radiologic study was obtained | | Supplemental—highly recommended |
| C18888 | Imaging acquisition reason other text | The free-text field related to 'Imaging acquisition reason' specifying other text. Describes why the imaging study was performed | | Supplemental—highly recommended |
| C13751 | Imaging acquisition reason | Describes why the imaging study was performed | Diagnostic; post-treatment; monitoring | Supplemental—highly recommended |
| C18701 | Imaging modality other text | The free-text field related to 'Imaging modality type' specifying other text. Type of radiologic study performed on the participant/subject | | Core |
| C02437 modified | Imaging modality type | Type of radiologic study performed on the participant/subject | Non-contrast CT; contrast CT; post-contrast CT; CT-angiography; CT perfusion; CBCT; PET; SPECT; MRI; non-contrast MRI; contrast MRI; MRI-angiography; MRI perfusion; X-Ray angiography; OCT; microscopy; MEG; EEG; MEG; DEXA; ultrasound | Core |
| C18718 | Imaging scanner strength other text | The free-text field related to 'Imaging scanner strength value' specifying other text. Value, in Tesla (T), of the scanner's magnetic field strength used for the scan being reported | | Supplemental |
| C02495 | Imaging scanner strength value | Value, in Tesla (T), of the scanner's magnetic field strength used for the scan being reported | 1.5; 3.0; 4.0; 7.0 | Supplemental |
| C18708 | Imaging pulse sequence other text | The free-text field related to 'Imaging pulse sequence type' specifying other text. Type of imaging pulse sequence used | | Supplemental |
| C02499 | Imaging pulse sequence type | Type of imaging pulse sequence used | T1; T2; FLAIR; DWI; GRE; SWI; DTI; MRSI; PWI; gradient-echo; pulsed-ASL; continuous-ASL; pseudocontinuous-ASL; post-contrast FLAIR; post-contrast T1-weighted; COW MRA; TOF Neck MRA; CE MRA; FLASH; MPRAGE; SPGR; SPACE/VISTA; TSE/FSE; dual echo PD/T2 W SE; PD SE; T2 W SE; T1 W SE; T1 W 3D gradient-echo; T1-weighted spin echo with contrast; T1-weighted spin echo without contrast; PD/T2W FSE; DIR; PSIR; fMRI; PRESS; spectroscopic imaging 2D; spectroscopic imaging 3D; Spin echo; STEAM; single voxel spectroscopy (SVS); pulsed-ASL; continuous-ASL; pseudocontinuous-ASL; multivoxel spectroscopy; unlocalized spectroscopy; ISIS; DWI/ADC; reduced field of view (rFOV); echo planar imaging (EPI) | Supplemental |

**Table 1 (continued)**

| CDE ID | CDE name | Definition | Permissible value | Classification |
|---|---|---|---|---|
| C08244 | Imaging slice thickness value | Value of the thickness of the slice measured in millimeters | | Supplemental—highly recommended |
| C13752 | Imaging computed tomography angiography (CTA) source used indicator | Indicates whether computed tomography angiography (CTA) source imaging was used | Yes; no; unknown | Supplemental—highly recommended |
| NEW | Imaging CT slice value | Value for the number of slices of the CT | 64; 128; 256; 320; other, specify | Supplemental |
| C13754 | Imaging CT settings window value | Value for the window of the CT window and level settings | | Supplemental |
| C13755 | Imaging CT settings level value | Value for the level of the CT window and level settings | | Supplemental |
| C18720 | Imaging visual analysis location performed other text | The free-text field related to 'Imaging visual analysis location performed type' specifying other text. Location where visual analysis of the imaging data is performed | | Supplemental |
| C08254 | Imaging visual analysis location performed type | Location where visual analysis of the imaging data is performed | Central; central read; local-site; local read; local report | Supplemental |
| C08255 | Imaging visual analysis blinded indicator | Indicator of whether the visual analysis was performed blinded to clinical data | Yes; no; unknown | Supplemental |
| C10931 | Imaging quality of images technically satisfactory indicator | Indicator of whether the quality of the images were technically satisfactory | Yes; no; unknown; not applicable | Supplemental |
| C02446 | Intraventricular hemorrhage status | Indicator of acute-appearing blood within the ventricles. | Present; absent; indeterminate | Supplemental—highly recommended |
| C13831 | Graeb intraventricular hemorrhage (IVH) scale—right lateral ventricle score | Indicates Graeb IVH scale—right lateral ventricle score | 1 (trace amount of blood or mild bleeding); 2 (< half of the ventricle filled with blood); 3 (> half of the ventricle filled with blood); 4 (ventricle expanded and filled with blood) | Supplemental—highly recommended |
| C13832 | Graeb intraventricular hemorrhage (IVH) scale—left lateral ventricle score | Indicates Graeb IVH scale—left lateral ventricle score | 1 (trace amount of blood or mild bleeding); 2 (< half of the ventricle filled with blood); 3 (> half of the ventricle filled with blood); 4 (ventricle expanded and filled with blood) | Supplemental—highly recommended |
| C13833 | Graeb intraventricular hemorrhage (IVH) scale—third ventricle score | Indicates Graeb IVH Scale—third ventricle score | 1 (blood present without dilatation); 2 (ventricle expanded and filled with blood) | Supplemental—highly recommended |
| C13834 | Graeb intraventricular hemorrhage (IVH) scale—fourth ventricle score | Indicates Graeb IVH scale—fourth ventricle score | 1 (blood present without dilatation); 2 (ventricle expanded and filled with blood) | Supplemental—highly recommended |
| C13835 | Graeb intraventricular hemorrhage (IVH) scale—total score | Indicates Graeb IVH scale—total score | | Supplemental—highly recommended |
| C02445 | Intraventricular hemorrhage volume measurement | Measured volume in cubic centimeters of intraventricular hemorrhage | | Supplemental—highly recommended |
| C02469 | Subarachnoid hemorrhage indicator | Indicator of macroscopic blood located between the brain surface and the arachnoid membrane. On CT and MR, the blood in this location will follow the contour of the sulci and cisterns. Acute SAH is hyperdense on CT and hyperintense on FLAIR MR imaging | Present; absent; indeterminate | Supplemental—highly recommended |

**Table 1 (continued)**

| CDE ID | CDE name | Definition | Permissible value | Classification |
|---|---|---|---|---|
| C13836 | Fisher grade | Indicates Fisher grade | 1 (no hemorrhage evident); 2 (SAH less than 1 mm thick); 3 (SAH more than 1 mm thick); 4 (SAH of any thickness with IVH or parenchymal extension) | Supplemental—highly recommended |
| C13837 | Modified Fisher scale grade | Indicates modified Fisher scale grade | 0 (No SAH or IVH) | Supplemental—highly recommended |
| | | | 1 (SAH less than 1 mm thick, no IVH); 2 (SAH less than 1 mm thick, with IVH); 3 (SAH more than 1 mm thick, no IVH); 4 (SAH more than 1 mm thick, with IVH) | |
| C13838 | Hijdra scale anatomic site | The site for the Hijdra scale assessment (the Hijdra et al. (1990) described a method to grade the amount of blood in the SA space and ventricles on CT) | Frontal; lateral sylvian right; lateral sylvian left; basilar sylvian right; basilar sylvian left; suprasellar right; suprasellar left; ambient right; ambient left; quadrigeminal; fourth ventricle; lateral ventricle right; lateral ventricle left | Supplemental |
| C13839 | Hijdra scale value | Indicates Hijdra scale—value | 0 (no amount of blood); 1 (small amount of blood (cisterns), sedimentation of blood in the posterior part (ventricles); 2 (moderately filled with blood (cisterns), partly filled with blood (ventricles); 3 (completely filled with blood) | Supplemental |
| C14050 | Hijdra scale total score | Indicates Hijdra scale—total score | | Supplemental |
| C13840 | Subdural hematoma present indicator | Indicates presence of subdural hematoma | Yes; no; unknown | Supplemental—highly recommended |
| C13841 | Subdural hematoma type | Indicates subdural hematoma type | Acute; subacute; chronic; lengthy; prolonged | Supplemental—highly recommended |
| C13845 | Imaging shift present indicator | Indicates if any shift present | Yes; No; Unknown | Supplemental |
| C13846 | Imaging shift type | Indicates shift type | Midline shift; septal shift; pineal shift | Supplemental |
| C13847 | Imaging shift measurement | Indicates shift measurement | | Supplemental |
| C13848 | Hydrocephalus present indicator | Indicates if hydrocephalus is present | Yes; no; unknown | Supplemental—highly recommended |
| C13849 | Bicaudate index score | Indicates Bicaudate index | | Supplemental |
| C13850 | Arteriovenous malformation present indicator | Indicates if arteriovenous malformation is present | Yes; No; Unknown | Supplemental—Highly Recommended |
| C13851 | Arteriovenous malformation anatomic site | Specifies location of arteriovenous malformation | | Supplemental—highly recommended |
| NEW | Barrow Neurological Institute (BNI) Scale–Aneurysmal subarachnoid hemorrhage thickness scale | BNI scale measures increasing SAH thickness on a quantitative scale and is used to predict the likelihood to develop symptomatic vasospasm | 1 (no blood); 2 (SAH $\leq$ 5 mm); 3 (SAH 5 $\leq$ 10 mm); 4 (SAH 10 $\leq$ 15 mm); 5 (SAH > 15 mm) | Supplemental |

*ADC* Apparent diffusion coefficient, *ASL* Arterial spin labeling, *CBCT* Cone-beam computed tomography, *CDE* Common data element,*CE* Contrast-enhanced, *COW* Circle of Willis, *CT* Computed tomography, *DEXA* Dual-energy x-ray absorptiometry, *DIR* Double inversion recovery, *DTI* Diffusion tensor imaging, *DWI* Diffusion weighted imaging, *EEG* Electroencephalography, *FLAIR* Fluid attenuated inversion recovery, *FLASH* Fast low angle shot imaging, *fMRI* Functional magnetic resonance imaging, *FSE* Fast spin echo, *GRE* Gradient echo imaging, *ID* Identification number, *ISIS* Image selected in vivo spectroscopy, *IVH* Intraventricular hemorrhage, *MEG* Magnetoencephalography, *MPRAGE* Magnetization prepared rapid gradient echo, *MRA* Magnetic resonance angiography, *MR* Magnetic resonance, *MRI* Magnetic resonance imaging, *MRSI* Magnetic resonance spectroscopic imaging, *OCT* Optical coherence tomography, *PD* Proton density, *PET* Positron emission tomography, *PRESS* Point resolved spectroscopy, *PSIR* Phase sensitive inversion recovery, *PWI* Perfusion weighted imaging, *SA* Subarachnoid, *SAH* Subarachnoid hemorrhage, *SE* Spin echo, *SPACE* Sampling perfection with application optimized contrast using different flip angle evolution, *SPECT* Single photon emission computed tomography, *SPGR* Spoiled gradient, *STEAM* Stimulated echo acquisition method, *SWI* Susceptibility weighted imaging, *T1W* T1 weighted, *T2W* T2 weighted, *TOF* Time-of-flight, *TSE* Turbo spin echo, *VISTA* Volume isotropic turbo spin echo acquistion

**Table 2** CDEs—Angiography

| CDE ID | CDE name | Definition | Permissible value | Unit | Classification |
|---|---|---|---|---|---|
| Vascular imaging | | | | | |
| C13750 | Imaging study ID number | Unique identification number assigned to the study or assessment session | Alphanumeric | | Supplemental—highly recommended |
| C02494 | Imaging study date and time | Date (and time, if applicable and known), the radiologic study was obtained | Date Time | Month/Day/Year Hours:minutes | Supplemental—highly recommended |
| C18888 | Imaging acquisition reason other text | The free-text field related to 'Imaging acquisition reason' specifying other text. Describes why the imaging study was performed | Alphanumeric | | Supplemental—highly recommended |
| C13751 | Imaging acquisition reason | Describes why the imaging study was performed | Diagnostic Post-treatment Monitoring | | Supplemental—highly recommended |
| C13879 modified | Imaging modality vessel imaging angiography type | Indicates imaging modality for vessel imaging angiography | DSA MRA CTA CBCT | | Core |
| C13880 | Digital subtraction angiography (DSA) site of access anatomic site | The site of access for digital subtraction angiography (DSA), a type of fluoroscopy technique used in interventional radiology to clearly visualize blood vessels in a bony or dense soft tissue environment | Brachial Radial Femoral Other | | Exploratory |
| C13881 | Digital subtraction angiography (DSA) injection site anatomic site | The site of injection for digital subtraction angiography (DSA), a type of fluoroscopy technique used in interventional radiology to clearly visualize blood vessels in a bony or dense soft tissue environment | Arch Common carotid Internal carotid Vertebral Subclavian | | Exploratory |
| C02411 | Laterality type | Laterality type relative to the anatomic site of the body examined or affected | | | Supplemental |
| C13882 | Magnetic resonance angiography type | The type as related to magnetic resonance angiography (MRA) | Alphanumeric | | Supplemental—highly recommended |
| C13883 | Computer tomography (CT) angiography type | The type of computer tomography angiography being performed | Head Neck Computer tomography venography (CTV) | | Supplemental—highly recommended |
| C08254 | Imaging visual analysis location performed type | Location where visual analysis of the imaging data is performed | Central Central read local site Local read Local report | | Supplemental |

**Table 2 (continued)**

| CDE ID | CDE name | Definition | Permissible value | Unit | Classification |
|---|---|---|---|---|---|
| C18720 | Imaging visual analysis location performed other text | The free-text field related to 'Imaging visual analysis location performed type' specifying other text. Location where visual analysis of the imaging data is performed | Alphanumeric | | Supplemental |
| C08255 | Imaging visual analysis blinded indicator | Indicator of whether the visual analysis was performed blinded to clinical data | Yes<br>No<br>Unknown | | Supplemental |
| C10931 | Imaging quality of images technically satisfactory indicator | Indicator of whether the quality of the images was technically satisfactory | Yes<br>No<br>Unknown<br>Not applicable | | Supplemental |
| C13884 | Imaging vessel angiography arterial anatomic site | Indicates vessel imaging angiography arterial findings location | CCA origin<br>CCA to bifurcation<br>ICA at origin<br>C1 cervical<br>C2 petrous<br>C3 lacerum<br>C4 cavernous<br>C5 clinoidal<br>C6 ophthalmic to PCOM<br>C6 PCOM to terminus<br>A1<br>A2<br>M1 proximal to striate<br>M1 distal to striate<br>M2 single<br>M2 multiple<br>M3 single<br>M3 multiple<br>M4 single<br>M4 multiple<br>Vertebral origin<br>Vertebral—cervical<br>Vertebral—intracranial proximal to PICA<br>Vertebral—distal to PICA<br>Basilar—distal to AICA<br>Basilar—mid<br>Basilar—proximal to AICA<br>PCOM<br>P1<br>P2<br>P3<br>SCA<br>AICA<br>PICA | | Core |
| C13885 | Imaging vessel angiography arterial result | Indicates vessel imaging angiography arterial findings | Normal<br>Occlusion<br>Aneurysm<br>Stenosis<br>AVM<br>Not visualized | | Core |
| C13896 | Imaging vessel angiography level of confidence status | Indicates vessel angiography level of confidence | Low<br>Moderate<br>High | | Supplemental—highly recommended |

**Table 2 (continued)**

| CDE ID | CDE name | Definition | Permissible value | Unit | Classification |
|---|---|---|---|---|---|
| NEW | Imaging aneurysm shape type | Shape/pathology of aneurysm for each unruptured intracranial aneurysm | Saccular<br>Fusiform<br>Dissecting | | Supplemental |
| NEW | Imaging vessel angiography aneurysm anatomic site | Anatomical site of aneurysm in vessel imaging angiography | C1 cervical<br>C2 petrous<br>C3 lacerum<br>C4 cavernous<br>C5 clinoidal<br>C6 ophthalmic to PCOM<br>C6 PCOM to terminus<br>A1<br>A2<br>M1 proximal to striate<br>M1 distal to striate<br>M2 single<br>M2 multiple<br>M3 single<br>M3 multiple<br>M4 single<br>M4 multiple<br>Vertebral—intracranial proximal to PICA<br>Vertebral—distal to PICA<br>Basilar—distal to AICA<br>Basilar—mid<br>Basilar—proximal to AICA<br>PCOM<br>P1<br>P2<br>P3<br>SCA<br>AICA<br>PICA | | Supplemental—highly recommended |
| NEW | Imaging aneurysm anatomic site | Aneurysm location | Cavernous<br>Persistent trigeminal<br>Medial paraclinoid<br>Lateral paraclinoid<br>Ophthalmic<br>Superior hypophyseal<br>Posterior communicating<br>Anterior choroidal<br>Internal carotid artery bifurcation<br>Middle cerebral artery bifurcation<br>Anterior communicating<br>Pericallosal<br>Posterior inferior cerebellar artery<br>Superior cerebellar<br>Basilar apex<br>other | | Supplemental—highly recommended |
| NEW | Imaging aneurysm dome measurement | Maximum diameter | Number | Millimeter | Supplemental—highly recommended |
| NEW | Imaging aneurysm neck measurement | Maximum diameter or width of aneurysm neck for each aneurysm | Number | Millimeter | Supplemental—highly recommended |

**Table 2  (continued)**

| CDE ID | CDE name | Definition | Permissible value | Unit | Classification |
|---|---|---|---|---|---|
| NEW | Imaging aneurysm lobe irregularity indicator | Presence of daughter lobes or aneurysm lobe irregularity | Yes No Unknown | | Supplemental |
| NEW | Imaging unruptured intracranial aneurysm morphology type | Morphology type of aneurysm for each unruptured intracranial aneurysm | A: Regular B: Bleb C: Daughter-sac, mul-tilobed aneurysm | | Supplemental—highly recommended |
| NEW | Imaging aneurysm aspect ratio value | Maximum height divided by largest neck diameter for each aneurysm | Number | Millimeter | Supplemental—highly recommended |
| NEW | Imaging aneurysm thrombus indicator | Presence of mural thrombus or partial thrombosis in aneurysm | Yes No Unknown | | Supplemental |
| C13885 | Imaging vessel angiography arterial result | Indicates vessel imaging angiography arterial findings | Normal Occlusion Aneurysm Stenosis AVM Not visualized | | Supplemental |
| C13886 modified | Imaging vessel angiography cause type | Indicates vessel imaging angiography cause | Atherosclerotic Embolic Other Unknown Vasospasm | | Supplemental |
| C13887 | Imaging vessel angiography symptomology type | Indicates vessel imaging angiography symptomology | Symptomatic Asymptomatic Indeterminate | | Supplemental |
| C14006 | Imaging stenosis percentage value | Indicates stenosis percentage value | Number | Percent | Supplemental |
| NEW | Imaging aneurysm 3D reconstruction indicator | Presence of 3D reconstruction of aneurysm | Yes No Unknown | | Supplemental |
| Endovascular treatment | | | | | |
| NEW | Aneurysm wall apposition status | Wall apposition for stents or flow diverters | Good Poor Unknown | | Supplemental |
| NEW | Aneurysm occlusion percentage value | Indicates the occlusion percentage of aneurysm | Number | Percent | Supplemental—highly recommended |
| NEW | Imaging aneurysm occlusion Raymond–Roy classification category | Raymond–Roy occlusion Classification of intracranial aneurysms | Complete occlusion Dog ear Residual neck Residual aneurysm | | Supplemental—highly recommended |
| NEW | Imaging aneurysm parent branch vessel occlusion indicator | Indicates occlusion of parent vessel or branch vessel related to aneurysm | Yes No Unknown | | Supplemental |
| Computational fluid dynamics: Volumetric factors | | | | | |
| NEW | Imaging aneurysm mean kinetic energy measurement | Indicates mean aneurysm kinetic energy measurement | Number | | Exploratory |
| C13948 | Imaging mean blood velocity measurement | Indicates mean velocity measurement | Number | cm/sec | Exploratory |
| NEW | Imaging aneurysm mean shear rate | Measure of the deformation of the fluid elements | Number | | Exploratory |
| NEW | Imaging aneurysm mean vorticity measurement | Measure of the rotational velocity of fluid elements | Number | | Exploratory |

**Table 2** (continued)

| CDE ID | CDE name | Definition | Permissible value | Unit | Classification |
|---|---|---|---|---|---|
| NEW | Imaging aneurysm mean viscous dissipation measurement | Indicates mean aneurysm viscous dissipation | Number | | Exploratory |
| NEW | Imaging aneurysm vortex coreline length measurement | Indicates vortex coreline length, a measure of complexity of the intra-aneurysmal flow pattern | Number | Centimeter | Exploratory |
| Computational fluid dynamics: Surface factors | | | | | |
| NEW | Aneurysm mean wall shear stress measurement | Indicates the mean aneurysm wall shear stress | Number | dyne/cm$^2$ | Supplemental |
| NEW | Aneurysm maximum wall shear stress measurement | Indicates the maximum aneurysm wall shear stress | Number | dyne/cm$^2$ | Supplemental |
| NEW | Aneurysm minimum wall shear stress measurement | Indicates the minimum aneurysm wall shear stress | Number | dyne/cm$^2$ | Supplemental |
| NEW | Aneurysm shear concentration index measurement | measures the degree of concentration of the wall shear stress distribution | Number | | Exploratory |
| NEW | Aneurysm low shear area percentage value | Indicates the percentage of the aneurysm area under low wall shear stress relative to the parent vasculature | Number | Percent | Exploratory |
| NEW | Aneurysm oscillatory shear index measurement | Indicates the mean aneurysm oscillatory shear stress | Number | | Exploratory |
| Computational fluid dynamics: Hemodynamic factors | | | | | |
| NEW | Aneurysm mean inflow rate measurement | Indicates mean aneurysm inflow rate | Number | ml/sec | Exploratory |
| NEW | Aneurysm inflow concentration index measurement | Measures the degree of concentration of the flow stream entering the aneurysm, percentage of the flow rate of the parent artery that enters the aneurysm divided by the percentage of the aneurysm ostium area that corresponds to positive inflow velocity | Number | | Exploratory |

*ACOM* Anterior communicating artery, *AICA* Anterior inferior cerebellar artery, *AVM* Arteriovenous malformation, *CBCT* Cone-beam computed tomography, *CCA* Common carotid artery, *CDE* Common data element, *CTA* Computed tomography angiography, *DSA* Digital subtraction angiography, *ICA* Internal carotid artery, *ID* Identification number, *MRA* Magnetic resonance angiography, *PCOM* Posterior communicating artery, *PICA* Posterior inferior cerebellar artery, *SCA* Superior cerebellar artery

### Perfusion Imaging

For 'Perfusion imaging,' we compiled 20 CDEs. Of these 14 CDEs reused and six CDEs were newly created. Specific parameters included mean transit time, cerebral blood flow, cerebral blood volume, time to peak, and time to maximum of the residue function. Other important Supplemental (but not highly recommended CDEs) included processing methods (deconvolution or not) and specific thresholds chosen to define a perfusion abnormality. None was classified as core.

The five Supplemental—Highly Recommended CDEs were:

- Imaging study ID number
- Imaging study date and time
- Acquisition reason
- Acquisition reason other text
- Imaging slice thickness value

**Table 3 CDEs—Perfusion imaging**

| CDE ID | CDE name | Definition | Permissible value | Classification |
|---|---|---|---|---|
| C13750 | Imaging study ID number | Unique identification number assigned to the study or assessment session | Alphanumeric | Supplemental—highly recommended |
| C02494 | Imaging study date and time | Date (and time, if applicable and known), the radiologic study was obtained | | Supplemental—highly recommended |
| C18888 | Imaging acquisition reason other text | The free-text field related to 'Imaging acquisition reason' specifying other text. Describes why the imaging study was performed | | Supplemental—highly recommended |
| C13751 | Imaging acquisition reason | Describes why the imaging study was performed | Diagnostic; post-treatment; monitoring | Supplemental—highly recommended |
| C18701 | Imaging modality other text | The free-text field related to 'Imaging modality type' specifying other text. Type of radiologic study performed on the participant/subject | | Supplemental |
| C02437 modified | Imaging modality type | Type of radiologic study performed on the participant/subject | Non-contrast CT; contrast CT; post-contrast CT; CT-angiography; CT perfusion; CBCT; PET; SPECT; MRI; non-contrast MRI; contrast MRI; MRI angiography; MRI perfusion; X-ray angiography; OCT; microscopy; MEG; EEG; MEG; DEXA; ultrasound | Supplemental |
| NEW | Imaging CT slice value | Value for the number of slices of the CT | 64; 128; 256; 320; other, specify | Supplemental |
| C18718 | Imaging scanner strength other text | The free-text field related to 'Imaging scanner strength value' specifying other text. Value, in Tesla (T), of the scanner's magnetic field strength used for the scan being reported | | Supplemental |
| C02495 | Imaging scanner strength value | Value, in Tesla (T), of the scanner's magnetic field strength used for the scan being reported | 1.5; 3.0; 4.0; 7.0 | Supplemental |
| C08244 | Imaging slice thickness value | Value of the thickness of the slice measured in millimeters | | Supplemental—highly recommended |
| C18720 | Imaging visual analysis location performed other text | The free-text field related to 'Imaging visual analysis location performed type' specifying other text. Location where visual analysis of the imaging data is performed | | Supplemental |
| C08254 | Imaging visual analysis location performed type | Location where visual analysis of the imaging data is performed | Central; central read; local-site; local read; local report | Supplemental |
| C08255 | Imaging visual analysis blinded indicator | Indicator of whether the visual analysis is performed blinded to clinical data | Yes; no; unknown | Supplemental |
| C10931 | Imaging quality of images technically satisfactory indicator | Indicator of whether the quality of the images was technically satisfactory | Yes; no; unknown; not applicable | Supplemental |
| NEW | Perfusion imaging modality type | Type of radiologic perfusion study | CT; MR | Supplemental |
| NEW | Perfusion imaging calculation method type | Indicates method used for perfusion calculation | No deconvolution; deconvolution without delay correction; deconvolution with delay correction | Supplemental |

**Table 3 (continued)**

| CDE ID | CDE name | Definition | Permissible value | Classification |
|--------|----------|------------|-------------------|----------------|
| NEW | Perfusion imaging parameter abnormality type | Indicates perfusion parameter used to delineate abnormality | Mean transit time lesion volume; time to peak lesion volume; cerebral blood volume (CBV) defect volume; time-to-max (Tmax) lesion volume; cerebral blood flow (CBF lesion volume | Supplemental |
| NEW | Perfusion imaging parameter threshold result | Indicates threshold value for abnormality | | Supplemental |
| NEW | Perfusion imaging parameter volume measurement | Indicates volume of perfusion abnormality | | Supplemental |
| C13875 | Imaging perfusion computed tomography based identification perfusion defect result | Result of perfusion CT (PCT) based identification of perfusion defect value of abnormality | | Supplemental |

*CBCT* Cone-beam computed tomography, *CDE* Common data element, *CT* Computed tomography, *DEXA* Dual-energy x-ray absorptiometry, *EEG* Electroencephalography, *ID* Identification number, *MEG* Magnetoencephalography, *MR* Magnetic resonance, *MRI* Magnetic resonance imaging, *OCT* Optical coherence tomography, *PET* Positron emission tomography, *SPECT* Single photon emission computed tomography

The remaining 15 Supplemental elements are listed in Table 3.

### Transcranial Doppler

There are 55 CDEs in the category 'Transcranial doppler,' all of them were reutilized from NINDS CDEs. None was classified as core.

The four Supplemental—Highly Recommended CDEs were:

- Imaging study ID number
- Imaging study date and time
- Acquisition reason
- Acquisition reason other text

We classified the remaining 51 CDEs as Exploratory (Table 4).

### Discussion

Imaging plays a key role in clinical research related to UIA and SAH. Therefore, clear, consistent definitions to describe different imaging modalities, techniques and findings are critical for communicating and comparing data between studies. This paper describes the recommendations, and the process by which they were developed, from a group of experienced clinical investigators for Imaging CDEs for UIA and SAH. The WG was able to incorporate many ($n = 100$) existing CDEs that were developed for ischemic stroke by the NINDS CDE WGs. An additional 36 CDEs were newly defined.

The WG created four main categories to encompass these CDEs. These categories can be thought of as menus and mirror the categories created for the NINDS CDEs. Their purpose is to aid investigators searching for relevant CDEs when designing their studies and developing case report forms. Many of these CDEs and their categories are pulled directly from the NINDS stroke CDEs. Parenchymal Imaging was used to capture findings from cross-sectional imaging (CT and MR), and to characterize hemorrhage (including the subarachnoid and intraventricular spaces). Some of these CDEs, such as the modified Fisher scale, have substantial validation as predictors of outcome [6]. The category of Angiography was created to encompass vascular imaging, endovascular treatment, and CFD parameters. Perfusion imaging was developed for capturing these parameters which are largely relevant to SAH-induced vasospasm. Finally, the group created a separate category for transcranial Doppler, as it did not fit neatly into the other categories.

Two new CDEs were created within Parenchymal Imaging. The first defines the number of CT slices for the CT scanner (e.g., 16, 64, 128 etc.). The second was to add the Barrow Neurological Institute Scale for definition of aneurysmal SAH thickness as a Supplemental CDE [8]. The Fisher, modified Fisher, Hijdra, and Graeb scales already existed within the NINDS Stroke CDEs and were pulled over [4–6, 9].

Twenty-seven new CDEs were developed for angiography. Many related to the emerging data for aneurysm morphology (such as aspect ratio), angiographic results after treatment [7], and the use of CFD [10, 11]. Many of the morphologic and CFD factors are associated with a history of rupture and may have a role in the prediction of future rupture. Prospective studies will be needed to establish these as risk factors. Use of these CDEs will help with comparisons between these future studies and to drive standardization for these definitions. This is particularly a problem for CFD parameters which can vary greatly between investigators [12, 13].

**Table 4 CDEs—Transcranial Doppler**

| CDE ID | CDE name | Definition | Permissible value | Classification |
|---|---|---|---|---|
| C13750 | Imaging study ID number | Unique identification number assigned to the study or assessment session | | Supplemental—highly recommended |
| C02494 | Imaging study date and time | Date (and time, if applicable and known), the radiologic study was obtained | | Supplemental—highly recommended |
| C18888 | Imaging acquisition reason other text | The free-text field related to 'Imaging acquisition reason' specifying other text. Describes why the imaging study was performed | | Supplemental—highly recommended |
| C13751 | Imaging acquisition reason | Describes why the imaging study was performed | Diagnostic; post-treatment; monitoring | Supplemental—highly recommended |
| C13899 | Imaging probe type text | The text describing the type of imaging probe | | Exploratory |
| C13900 | Imaging probe frequency | Indicates imaging probe frequency (Hz) | | Exploratory |
| C13901 | Imaging patient type | Indicates imaging patient type | Asymptomatic; acute stroke; chronic stroke; brain edema; vasospasm | Exploratory |
| C13902 | Imaging acute stroke study type | Indicates imaging acute stroke study type | Initial; follow-up 1; follow-up 2 | Exploratory |
| C13903 | Imaging interpretation site indicator | Indicates imaging interpretation site | | Exploratory |
| C13904 | Imaging interpretation offsite media type | Indicates imaging offsite media type | Video; print; digital | Exploratory |
| C10570 | Imaging contrast agent used indicator | Indicator as to whether an imaging contrast agent was used for the scan as part of diffusion tensor imaging (DTI) | Yes; no; unknown; not applicable | Exploratory |
| C18693 | Imaging contrast agent method other text | The free-text field related to 'Imaging contrast agent method type' specifying other text. Indicates imaging contrast agent method of administration | | Exploratory |
| C13905 | Imaging contrast agent method type | Indicates imaging contrast agent method of administration | Bolus; infusion; other, specify | Exploratory |
| C18720 | Imaging visual analysis location performed other text | The free-text field related to 'Imaging visual analysis location performed type' specifying other text. Location where visual analysis of the imaging data is performed | | Supplemental |
| C08254 | Imaging visual analysis location performed type | Location where visual analysis of the imaging data is performed | Central; central read; local-site; local read; local report | Supplemental |
| C08255 | Imaging visual analysis blinded indicator | Indicator of whether the visual analysis was performed blinded to clinical data | Yes; no; unknown | Supplemental |
| C10931 | Imaging quality of images technically satisfactory indicator | Indicator of whether the quality of the images were technically satisfactory | Yes; no; unknown; not applicable | Supplemental |
| C14008 | Imaging window quality category | Indicates window quality category | Temporal; posterior; orbital | Exploratory |
| C14009 | Imaging window quality result | Indicates window quality result for all categories | Fair; excellent; poor | Exploratory |
| C13942 | Imaging vessel category | Indicates vessel category | M1; insular M2; A1; internal carotid artery (ICA); P1; P2; EC ICA; siphon; vertebral; basilar; ophthalmic | Exploratory |
| C02411 | Laterality type | Laterality type relative to the anatomic site of the body examined or affected | | Exploratory |
| C14056 | Imaging depth measurement | The depth measurement (mm) of imaging | | Exploratory |

**Table 4  (continued)**

| CDE ID | CDE name | Definition | Permissible value | Classification |
|---|---|---|---|---|
| C13947 | Imaging peak velocity measurement | Indicates peak velocity measurement (cm/s) | | Exploratory |
| C13948 | Imaging mean blood velocity measurement | Indicates mean velocity measurement (cm/s) of blood | | Exploratory |
| C14007 | Imaging Transcranial Doppler (TCD) findings result type | Indicates Transcranial Doppler (TCD) findings | Reversed diastolic flow; systolic spike; no signals; reduced upstroke/pulsatility index (PI) | Exploratory |
| C13949 | Imaging flow/probe direction type | Indicates flow/probe direction | Toward; away from | Exploratory |
| C14037 | Imaging power M mode left middle cerebral artery result | Indicates power M mode for left middle cerebral artery (MCA) result | Absent; high resistance; low resistance | Exploratory |
| C14038 | Imaging power M mode right middle cerebral artery result | Indicates power M mode for right middle cerebral artery (MCA) result | Absent; high resistance; low resistance | Exploratory |
| C14034 | Vasomotor response (VMR) vessel anatomic site | Indicates vasomotor response (VMR) vessel type | M1; A1; P1; siphon; ophthalmic; vertebral; basilar; middle cerebral artery; other, specify | Exploratory |
| C18903 | Vasomotor response (VMR) vessel anatomic other text | The free-text field related to 'Vasomotor response (VMR) vessel anatomic site' specifying other text. Indicates vasomotor response (VMR) vessel type | | Exploratory |
| C14035 | VMR response result | Indicates vasomotor response (VMR) response result | Abnormal; normal | Exploratory |
| C14036 | Breath-holding index result | Indicates Breath-holding index (BHI) result | | Exploratory |
| C14000 | Extracranial stenosis present indicator | Indicates presence of extracranial stenosis | Yes; no; unknown | Exploratory |
| C14001 | Extracranial stenosis type | Indicates extracranial stenosis type | Collateral; reduced upstroke; reduced pulsatility index (PI); VMR; reduced velocity | Exploratory |
| C14002 | Extracranial stenosis collateral artery anatomic site | The site of parallel arteries having extracranial stenosis | Ophthalmic artery; anterior cerebral artery; vertebral artery | Exploratory |
| C14011 | Intracranial stenosis present indicator | Indicates presence of intracranial stenosis | Yes; no; unknown | Exploratory |
| C14010 | Intracranial stenosis collateral vessel anatomic site | Indicates intracranial stenosis collateral vessel(s) | Internal carotid artery; basilar; middle cerebral artery; anterior cerebral artery; vertebral artery; posterior cerebral artery; other, specify | Exploratory |
| C18900 | Intracranial stenosis collateral vessel anatomic other text | The free-text field related to 'Intracranial stenosis collateral vessel anatomic site' specifying other text. Indicates intracranial stenosis collateral vessel(s) | | Exploratory |
| C14006 | Imaging stenosis percentage value | Indicates stenosis percentage value | | Exploratory |
| C14012 | Intracranial stenosis peak systolic velocity (PSV) criterion result | Indicates intracranial stenosis peak systolic velocity (PSV) criterion | | Exploratory |
| C14013 | Intracranial stenosis mean velocity criterion value | Indicates intracranial stenosis mean velocity criterion | | Exploratory |
| C14014 | Intracranial stenosis other criteria result | Other criteria for intracranial stenosis | | Exploratory |
| C14028 | Vasospasm present indicator | Indicates presence of vasospasm | Yes; no; unknown | Exploratory |
| C14031 | Vasospasm status | Indicates vasospasm result | Abnormal; normal | Exploratory |
| C14032 | Vasospasm severity grade | Indicates severity of vasospasm | Mild; moderate; severe | Exploratory |

**Table 4** (continued)

| CDE ID | CDE name | Definition | Permissible value | Classification |
|--------|----------|------------|-------------------|----------------|
| C18902 | Vasospasm vessel anatomic other text | The free-text field related to 'Vasospasm vessel anatomic site' specifying other text. Indicates vasospasm vessel(s) | | Exploratory |
| C14033 | Vasospasm vessel anatomic site | Indicates vasospasm vessel(s) | Internal carotid artery; basilar; middle cerebral artery; anterior cerebral artery; vertebral artery; other, specify | Exploratory |
| C14024 | Vasospasm criterion value | Indicates vasospasm criterion value | | Exploratory |
| C14025 | Vasospasm Lindegaard ratio value | Indicates vasospasm Lindegaard ratio result | | Exploratory |
| C14029 | Vasospasm posterior ratio result | Indicates vasospasm posterior ratio result | | Exploratory |
| C14026 | Intracranial pressure imaging result | Indicates intracranial pressure (ICP) imaging result | | Exploratory |
| C14030 | Vasospasm resistive index indicator | Indicates vasospasm resistive index (RI) | Yes; no; unknown | Exploratory |
| C14027 | Intracranial pressure (ICP) other measurement text | Indicates other method of measuring intracranial pressure (ICP) | | Exploratory |
| C01559 | Arterial partial pressure carbon dioxide value | Measurement of how much carbon dioxide is dissolved in the arterial blood and how well carbon dioxide can move out of the body (PaCO2) | | Exploratory |
| C14052 | Hemoglobin measurement | The measurement for hemoglobin | | Exploratory |

*CDE* Common data element, *EC* Extracranial, *ICA* Internal carotid artery, *ID* Identification numbe, *M* mode Motion mode, *VMR* Vasomotor response

Perfusion imaging in SAH-induced vasospasm is also an emerging area in need of validation and standardization for both prediction and diagnosis [14]. Most perfusion imaging CDEs were taken from the existing stroke CDE menu, and six new ones were created, which are related to calculation methodology and definition of thresholds for abnormalities. Finally, all 55 CDEs for transcranial Doppler were carried forward from the stroke CDEs. No new ones were created

## Limitations

The proposed CDEs have limitations. The WG identified and defined numerous data elements for imaging studies and data in the setting of SAH, based on existing and/or most commonly used definitions. A balance was needed between very detailed definitions, which would decrease the feasibility of using these CDEs, and broad definitions, which are easier to use in clinical practice but may provide fewer scientific details. Thus, many of these definitions and their scientific implications lack prospective validation. Further, several CDEs were reused and in some cases adapted from established CDEs on other entities.

A consensus approach was used to define and rank the individual importance of data elements. Other potentially relevant data elements suggested could not be included at present because of the lack of validated imaging modalities or grading scales for such imaging outcomes. Additionally, together with the UIA Subcommittee, a novel classification system for aneurysm morphology (Fig. 2) was established and agreed on, for which there was no established data from the previous cohort or case–control studies to support this exact classification. However, since three-dimensional aneurysm morphologies are difficult to measure or to describe in standardized manner, a two-dimensional classification was agreed upon as a basis for further research. Lastly, the proposed CDEs on imaging in the setting of SAH will need to be adapted or even expanded in the future, once novel data or imaging techniques become available.

### Next Steps/Future Work

Future clinical studies will be needed to test and validate the relative importance of many of the SAH imaging CDEs described above. In addition, these CDEs will require updating in the future as further information is gained.

**Fig. 2** Classification of aneurysm morphology
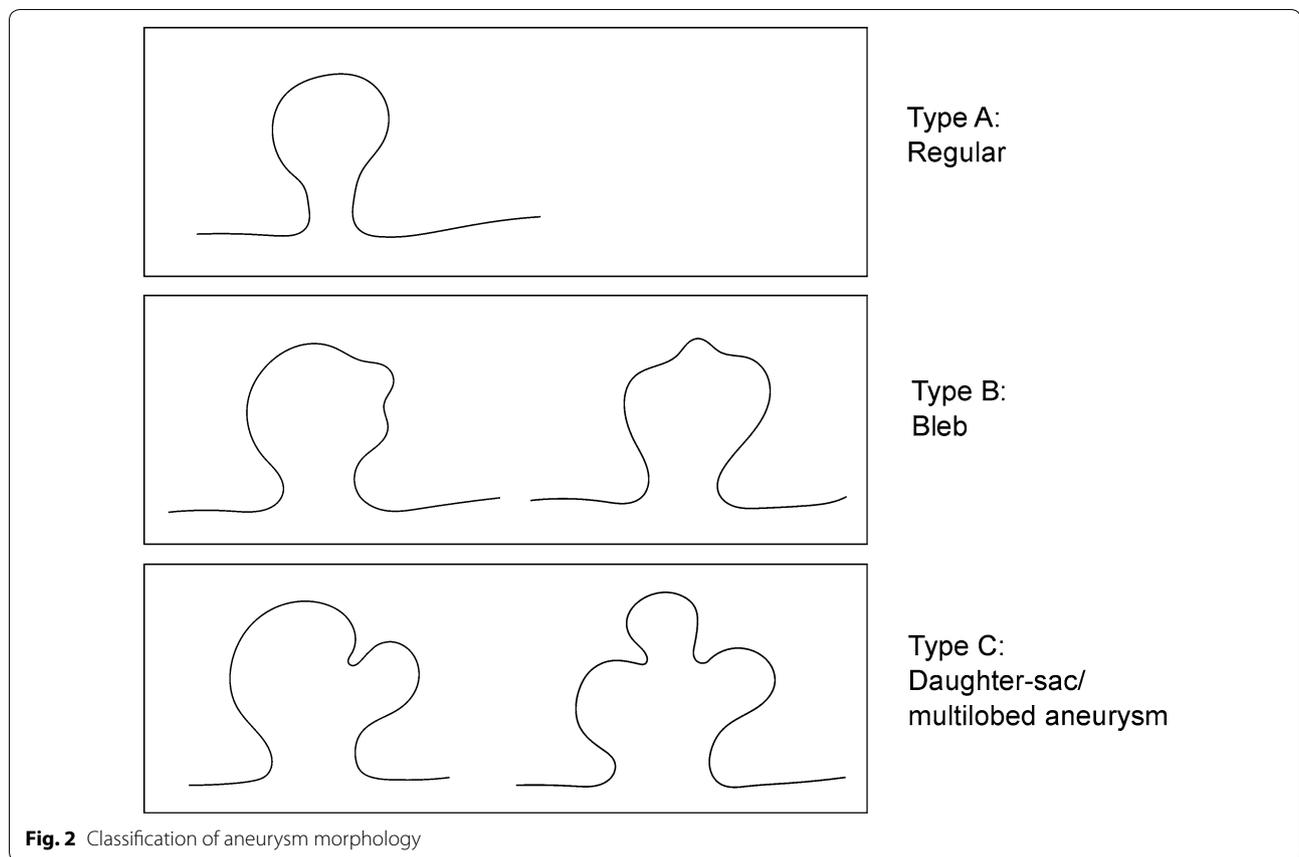
## Conclusions

A total of 136 CDEs were defined and categorized, 100 of them were derived from previously established CDEs on ischemic stroke and 36 which were newly created for the UIA and SAH CDE project. These imaging CDEs in the setting of UIAs and SAH will serve as a basis to aggregate imaging data, and help to harmonize data across studies. However, the CDEs remain to be validated, adapted and updated in the future based on novel data to optimize existing CDEs and establish new CDEs.

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**Conflict of interest**
Dr Hackenberg has nothing to disclose. Dr Etminan has nothing to disclose. Dr Wintermark has nothing to disclose. Dr Meyers has nothing to disclose. Dr Lanzino has nothing to disclose. Dr Rüfenacht has nothing to disclose. Dr Krings has nothing to disclose. Dr Huston has noting to disclose. Dr Rinkle has nothing to disclose. Dr Derdeyn reports personal fees from Penumbra, Inc, grants from Siemmens, Inc, outside of the submitted work.

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