**ONLINE SUPPLEMENTAY MATERIAL**

**Description of procedure codes for the treatment of intracranial aneurysms**

1. S4641

Surgical clipping of aneurysms that are <7 mm and located in the anterior circulation; anterior circulation includes the internal carotid artery and its branches (including the anterior cerebral artery and middle cerebral artery).

1. S4642

Surgical clipping of aneurysms that are ≥7 mm or aneurysms of any size located in the posterior circulation or aneurysms of any size that require removal of the anterior clinoid process or posterior clinoid process; posterior circulation includes the vertebro-basilar system.

1. M1661

Endovascular coiling of aneurysms requiring assisted coiling (e.g., stent-assisted coiling, balloon-assisted coiling, etc.).

1. M1662

Endovascular coiling of aneurysms that do not require assisted coiling.

**Claim guidelines of treatment for multiple aneurysms**

When submitting a claim, physicians should include the procedure code and the frequency based on the number of lesions treated. For example, the frequency is 1 if one aneurysm is treated, but if two aneurysms are treated at one-stage, the frequency is 1.5 (before August 1, 2014; limited to a hospital) or 1.7 (after August 1, 2014; limited to a general hospital or tertiary referral hospital) since payment for treatment of secondary lesions is 50% or 70% of the first lesion, except if the secondary lesion requires another incision and craniotomy at one-stage (e.g., aneurysms located at the right and left middle cerebral artery bifurcation). An alternative way to submit a claim when multiple lesions are treated at one-stage is to include the procedure sub-code that indicates treatment of secondary lesions (e.g., sub-codes S4641, S46410001, or S46410004). We could also identify the number of aneurysms through the frequency of procedure sub-codes.

In some specific frequency of surgical clipping, we could not identify the exact number of treated aneurysms. For instance, if the frequency was coded as 2, there are two possibilities: three treated aneurysms at one-stage or two treated aneurysms through two incisions (right and left) during one general endotracheal anesthesia. These patients were omitted because of missing values when identifying the aneurysm size because we did not identify the number of clips or coils for each aneurysm.

**Claim guidelines of reoperation**

Like claim guidelines for the treatment of multiple aneurysms, the frequency should be coded as 0.5 for reoperation before August 1, 2014. Alternatively, physicians can include procedure sub-codes indicating reoperation (e.g., sub-codes S4641 and S46410002). However, starting from August 1, 2014, these codes were deleted, and reoperations were charged equal to the charge of the primary operation. Therefore, we could not identify reoperation from then. When procedure codes with a frequency of 1 are entered separately and the frequency of general endotracheal anesthesia is more than two from August 1, 2014, we assumed it as reoperation even though it could be staged treatment.

Using this claim guideline of reoperation, we defined reoperation as follows:

1. The frequency of general endotracheal anesthesia was more than two and there were two separate procedure codes with frequencies of 0.5 and 1 before August 1, 2014.
2. The frequency of general endotracheal anesthesia was more than two and there were two separate procedure codes with a frequency of 1 after August 1, 2014.
3. Any procedure sub-code indicating reoperation regardless of the frequency of general endotracheal anesthesia.
4. Especially, patients undergoing endovascular coiling are coded as one endovascular coiling code with a frequency of 0.5 and one surgical clipping code with a frequency of 1 are considered as converted to surgical clipping immediately due to failure of endovascular coiling.

**Claim guidelines for coil usage**

Principally, physicians can use 1 coil per 1 mm of the maximal diameter of the aneurysm (e.g., 6 × mm, up to 6 coils).

However, additional coils can be used if the following conditions are satisfied:

1. Two additional coils can be used if the aneurysm size is >4 mm and <8 mm.
2. Two additional coils can be used if the aneurysm size is ≥8 mm.
3. Two additional coils can be used if the dome-neck ratio of the aneurysm is ≤1.5 or the neck diameter of the aneurysm is ≥4 mm.

**Allocation of the aneurysm size**

We allocated the size of the aneurysm as follows with consideration for claim guidelines of coil usage, clinical practice, and possibility of a coding error.

* **Definition of** ≥**7 mm**

1. Surgical clipping: code S4642 and >3 clips per aneurysm

(e.g., boosting clip)

1. Endovascular coiling: >10 coils per aneurysm

* **Definition of <7 mm**

1. Surgical clipping: code S4641 and 1 clip per aneurysm
2. Endovascular coiling: <5 coils per aneurysm

Aneurysms that were not included in the definitions above were omitted as missing values.

**Allocation of the aneurysm location**

We allocated the location of the aneurysm using the following algorithm with consideration for the procedure code of digital subtraction angiography and surgical clipping.



Figure I. Algorithm for identifying the location of the aneurysm



Figure II. Subgroup analysis for primary outcome

Yr, year; COPD, chronic obstructive pulmonary disease



**Coil**

**Clip**

Figure III. Unadjusted aneurysm rupture in the endovascular coiling and surgical clipping groups

CI, confidence interval



**Coil**

**Clip**

Figure IV. Unadjusted retreatment in the endovascular coiling and surgical clipping groups.

CI, confidence interval

Table I. Procedure codes for identifying another surgery

|  |  |
| --- | --- |
| S4633 | Craniotomy for Excision of Brain Tumor-Transnasal Excision of Pituitary Tumor |
| S4634 | Craniotomy for Excision of Brain Tumor-Supratentorial-Simple |
| S4635 | Craniotomy for Excision of Brain Tumor-Supratentorial-Complex |
| S4636 | Craniotomy for Excision of Brain Tumor-Infratentorial-Simple |
| S4637 | Craniotomy for Excision of Brain Tumor-Infratentorial-Complex |
| S4653 | Operation of Cerebral Arteriovenous Malformation-Intracranial-Simple |
| S4654 | Operation of Cerebral Arteriovenous Malformation-Intracranial-Complex |
| S4655 | Operation of Cerebral Arteriovenous Malformation-Dural-Simple |
| S4656 | Operation of Cerebral Arteriovenous Malformation-Dural-Complex |
| S4657 | Operation of Cerebral Arteriovenous Malformation-Cavernous Malformations-Simple |
| S4658 | Operation of Cerebral Arteriovenous Malformation-Cavernous Malformations-Complex |
| S4661 | Intracerebral Vascular Anastomosis-Direct |
| S4662 | Intracerebral Vascular Anastomosis-Indirect |
| S4670 | Carotid Artery Ligation |
| M1663 | Embolization-Cerebral/Arteriovenous Malformation/Cerebral |
| M1664 | Embolization-Cerebral/Arteriovenous Malformation/Dural Arteriovenous Fistula/Transarterial |
| M1665 | Embolization-Cerebral/Arteriovenous Malformation/Dural Arteriovenous Fistula/Transvenous |
| M1666 | Embolization-Cerebral/Arteriovenous Malformation/Caroticocavernous Fistula |
| M1671 | Embolization-Tumor/Brain |
| M1673 | Embolization-Tumor/Brain |

Table II. ICD-10 diagnosis codes for identifying hemorrhagic stroke, ischemic stroke and hyperlipidemia in baseline characteristics

|  |  |
| --- | --- |
| ICD-10 code | Diagnosis |
| I61 | Intracerebral hemorrhage |
| I61.0 | Intracerebral hemorrhage in hemisphere, subcortical |
| I61.1 | Intracerebral hemorrhage in hemisphere, cortical |
| I61.2 | Intracerebral hemorrhage in hemisphere, unspecified |
| I61.3 | Intracerebral hemorrhage in brain stem |
| I61.4 | Intracerebral hemorrhage in cerebellum |
| I61.5 | Intracerebral hemorrhage, intraventricular |
| I61.6 | Intracerebral hemorrhage, multiple localized |
| I61.8 | Other intracerebral hemorrhage |
| I61.9 | Intracerebral hemorrhage, unspecified |
| I62 | Other nontraumatic intracranial hemorrhage |
| I62.0 | Subdural hemorrhage (acute) (nontraumatic) |
| I62.1 | Nontraumatic extradural hemorrhage |
| I62.9 | Intracranial hemorrhage (nontraumatic), unspecified |
| I63 | Cerebral infarction |
| I63.0 | Cerebral infarction due to thrombosis of precerebral arteries |
| I63.1 | Cerebral infarction due to embolism of precerebral arteries |
| I63.2 | Cerebral infarction due to unspecified occlusion or stenosis of precerebral arteries |
| I63.3 | Cerebral infarction due to thrombosis of cerebral arteries |
| I63.4 | Cerebral infarction due to embolism of cerebral arteries |
| I63.5 | Cerebral infarction due to embolism of cerebral arteries |
| I63.6 | Cerebral infarction due to cerebral venous thrombosis, nonpyogenic |
| I63.8 | Other cerebral infarction |
| I63.9 | Cerebral infarction, unspecified |
| I69.1 | Sequelae of intracerebral hemorrhage |
| I69.2 | Sequelae of other nontraumatic intracranial hemorrhage |
| I69.3 | Sequelae of cerebral infarction |
| E78.5 | Hyperlipidemia, unspecified |

ICD-10, International Classification of Diseases, Tenth Revision

Table III. Procedure codes for identifying periprocedural outcomes

|  |  |
| --- | --- |
| S4621 | Craniotomy for Evacuation of Hematoma-Subdural or Extradural |
| S4622 | Craniotomy for Evacuation of Hematoma-Intracerebral |
| N0321 | Burr Hole or Trephination for Exploration |
| N0322 | Burr Hole or Trephination for Drainage And/Or Evacuation of Cyst, Hematoma, or Abscess (Sub or Epidural) |
| N0323 | Burr Hole or Trephination for Drainage And/Or Evacuation of Cyst, Hematoma, or Abscess (Intracerebral) |
| N0324 | Burr Hole or Trephination for Others |
| N0333 | Craniotomy or Craniectomy for Decompression |
| S4712 | Shunt Operation or Bypass Operation-Ventriculo-Other |
| O1300 | Invasive Tracheostomy |
| O1301 | Percutaneous Dilatational Tracheostomy |
| O7020 | Hemodialysis |
| O7031 | Continuous Venovenous Hemodialysis |
| O7032 | Continuous Venovenous Hemodialysis |
| O7033 | Continuous Arteriovenous Hemodialysis |
| O7034 | Continuous Arteriovenous Hemodialysis |
| OA641 | Vascular Bypass Operation (Aorta-Coronary), Simple |
| OA642 | Vascular Bypass Operation (Aorta-Coronary), Simple |
| OA647 | Vascular Bypass Operation (Aorta-Coronary), Complex |
| O1641 | Vascular Bypass Operation (Aorta-Coronary), Simple |
| O1642 | Vascular Bypass Operation (Aorta-Coronary), Simple |
| O1647 | Vascular Bypass Operation (Aorta-Coronary), Complex |
| M6551 | Percutaneous Transluminal Coronary Angioplasty-Single Vessel |
| M6552 | Percutaneous Transluminal Coronary Angioplasty-Additional Vessel |
| M6561 | Percutaneous Transcatheter Placement of Intracoronary Stent-Single Vessel |
| M6562 | Percutaneous Transcatheter Placement of Intracoronary Stent-Additional Vessel |
| M6563 | Percutaneous Transcatheter Placement of Intracoronary Stent |
| M6564 | Percutaneous Transcatheter Placement of Intracoronary Stent |
| M6571 | Percutaneous Transluminal Coronary Atherectomy-Single Vessel |
| M6572 | Percutaneous Transluminal Coronary Atherectomy-Additional Vessel |
| M6634 | Percutaneous Thrombus Removal-Thrombolytic Treatment-Coronary Artery |
| M6601 | Percutaneous Intravascular Installation of Metallic Stent-Cerebral |
| M6631 | Percutaneous Thrombus Removal-Thrombolytic Treatment-Cerebral |
| M6633 | Percutaneous Thrombus Removal-Mechanical Thrombolysis |
| X2021 | Packed RBC for Whole Blood 320 mL |
| X2022 | Packed RBC for Whole Blood 400 mL |
| X2031 | Washed RBC for Whole Blood 320 mL |
| X2032 | Washed RBC for Whole Blood 400 mL |
| X2091 | Leukocyte Poor Packed RBC for Whole Blood 320 mL |
| X2092 | Leukocyte Poor Packed RBC for Whole Blood 400 mL |
| X2111 | Leukocyte Filtered Packed RBC for Whole Blood 320 mL |
| X2112 | Leukocyte Filtered Packed RBC for Whole Blood 400 mL |
| HA601 | Vertebral Angiography |
| HA602 | Common Carotid Angiography |
| HA603 | External Carotid Angiography |
| HA604 | Internal Carotid Angiography |
| HA605 | 4 Vessel Angiography |

Table IV. Sensitivity analysis under several scenarios with assumption of MNAR

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Scenario** | **Location** | | | | **Size** | | | | **Mortality** | | **Hazard ratio**  **(95% CI)** | **P value** |
| **Anterior** | | **Posterior** | | **<7 mm** | | **≥7 mm** | |
| **Clip** | **Coil** | **Clip** | **Coil** | **Clip** | **Coil** | **Clip** | **Coil** | **Clip** | **Coil** |
| **1** | 99.3% | 90.0% | 0.7% | 10.0% | 51.3% | 78.5% | **48.7%** | 21.5% | 3.6% | 4.4% | 1.23  (0.97 to 1.58) | 0.09 |
| **2** | 99.3% | 90.0% | 0.7% | 10.0% | 81.7% | 48.7% | 18.3% | **55.3%** | 3.6% | 3.2% | 0.87  (0.67 to 1.11) | 0.27 |
| **3** | 99.3% | 90.0% | 0.7% | 10.0% | 51.8% | 44.3% | **48.2%** | **55.7%** | 3.6% | 3.6% | 1.00  (0.82 to 1.22) | 0.80 |
| **4** | 99.3% | 69.8% | 0.7% | **31.1%** | 81.7% | 78.5% | 18.3% | 21.5% | 3.6% | 3.3% | 1.01  (0.82 to 1.48) | 0.47 |
| **5** | 99.3% | 69.2% | 0.7% | **30.8%** | 51.7% | 78.5% | **48.3%** | 21.5% | 3.6% | 3.9% | 1.12  (0.80 to 1.57) | 0.44 |
| **6** | 99.3% | 69.2% | 0.7% | **30.8 %** | 81.7% | 44.7% | 18.3% | **55.3%** | 3.6% | 3.0% | 0.79  (0.59 to 1.06) | 0.14 |
| **7** | 99.3% | 69.4% | 0.7% | **30.6%** | 51.1% | 44.6% | **48.9%** | **55.4%** | 3.6% | 3.4% | 0.94  (0.70 to 1.26) | 0.48 |

MNAR, missing not at random; CI, confidence interval

Table V. Adjusted periprocedural outcomes after endovascular coiling or surgical clipping.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Periprocedural outcome | Endovascular coiling | | Surgical clipping | |  | P value |
|  | |  | |  | Hazard ratio |  |
| 30-day mortality\* | | 0.2% | | 0.2% | 0.91 (95% CI, 0.53 to 1.56) | 0.73† |
|  | |  | |  | Relative risk |  |
| Periprocedural rupture | | 1.6% | | 1.6% | 1.06 (95% CI, 0.87 to 1.30) | 0.81 |
| Reoperation | | 1.0% | | 0.6% | 1.68 (95% CI, 1.24 to 2.29) | <0.001 |
| Conversion to clipping from coiling | | 0.1% | | NA | NA | NA |
| EDH or SDH requiring removal operation | | NA | | 0.5% | NA | NA |
| ICH requiring removal operation | | 0.1% | | 0.3% | 0.22 (95% CI, 0.10 to 0.47) | <0.001 |
| Decompressive craniectomy | | 0.1% | | 0.2% | 0.44 (95% CI, 0.17 to 1.14) | 0.07 |
| Cerebral thromboembolic event‡ | | 0.4% | | <0.1% | 9.46 (95% CI, 3.74 to 23.93) | <0.001 |
| Myocardial infarction§ | | 0.1% | | 0.1% | 1.59 (95% CI, 0.56 to 4.48) | 0.35 |
| Hemodialysis | | 0.3% | | 0.2% | 1.17 (95% CI, 0.69 to 1.97) | 0.55 |
| Transfusion of red blood cell | | 2.6% | | 24.0% | 0.11 (95% CI, 0.10 to 0.12) | <0.001 |
| Tracheostomy | | 0.2% | | 0.5% | 0.40 (95% CI, 0.23 to 0.71) | <0.001 |
| Length of hospitalization| | | | 4 days  (IQR, 3 to 7) | | 11 days  (IQR, 8 to 16) | NA | <0.001 |
| Transfer to other hospital  and staying more than 30 days# | | 0.4% | | 1.4% | 0.28 (95% CI, 0.19 to 0.40) | <0.001 |

\*Percentage of 30-day mortality is Kaplan-Meier estimate.

†P-value of 30-day mortality was estimated using the Log-rank test.

‡Cerebral thromboembolic events were defined as any event requiring endovascular thrombolysis or mechanical thrombectomy.

§Myocardial infarction was defined as any event requiring endovascular or surgical intervention.

| |Length of hospitalization was presented with the use of median and interquartile range.

#We defined patients who were transferred to other hospitals and stayed more than 30 days to exclude patients who were immediately admitted to another hospital after discharge for the purpose of recovery.

EDH, epidural hematoma; SDH, subdural hematoma; ICH, intracranial hemorrhage; NA, not applicable; IQR, interquartile range; CI, confidence interval.