# Optimizing Radiation Protection for Patients in Cerebral Angiography: the possibility of establishing diagnostic reference levels by imaging objectives/ disease groups

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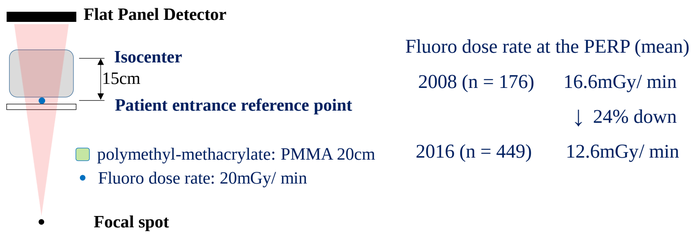
## Introduction

Japan Network for Research and Information on Medical Exposures (**J-RIME**) proposed the introduction of diagnostic reference levels (Japan DRLs) in June, 2015. In this Japan DRLs, the radiation dose rate of 20 mGy/min at the patient entrance reference point (PERP) determined in the phantom experiment was defined as the DRL for the quality control on the modality side.

Optimization of protection for patients is progressing by using the imaging apparatus according to the Japan DRLs.

**Japan DRLs 2015 (IVR)**




| | Fluoro dose rate at the PERP (mean) |
|---|---|
| 2008 (n = 176) | 16.6mGy/ min |
| ↓ 24% down | |
| 2016 (n = 449) | 12.6mGy/ min |

## Four years have passed since Japan DRL was introduced. The time for revision has come.

### Purpose

ICRP Publication 135 states that the DRL needs considering the complexity of the interventional radiology (IVR) procedure. We set **air kerma area product ($P_{KA}$)** and **air kerma at PERP ($K_{a,r}$)** displayed on cerebral angiography devices as the DRL quantities in this study for the next revision of the Japan DRL. In addition, to include factors that complicate the procedures, categorization by imaging objectives of cerebral angiography and by disease names was attempted.

## Methods

1. A total of 997 patients who underwent cerebral angiography at our hospital was divided into a neuro IVR group (n = 288) and a diagnostic cerebral angiography group (n = 709) (Table 1). Both $P_{KA}$ and $K_{a,r}$ recorded during the operation were collected and compared by using the Mann-Whitney test.
2. Each group was categorized into nine disorder subgroups: cerebral aneurysm, arteriovenous malformation, dural arteriovenous fistula, carotid artery stenosis/obstruction, acute cerebral infarction, brain tumor, cerebral vasospasm, other hemorrhagic disease, and other ischemic disease. Significant differences between each disease group were compared using the Kruskal-Wallis test.
3. Steel-Dwass multiple comparison test was used among each group for the statistical study.

**Table 1 Characteristics of 997 cerebral angiography cases (February 2012-March 2016)**

| | Neuro IVR | Diagnostic cerebral angiography |
|---|---|---|
| Number of cases | 288 | 709 |
| Man/Woman | 135 (47 %)/153 (53 %) | 422 (60 %)/287 (40 %) |
| Age | 67 ± 16* [range: 16—95] | 62 ± 15* [range: 5—95] |
| Disease group | | |
| Cerebral aneurysm | 125 | 191 |
| Arteriovenous malformation | 18 | 26 |
| Dural arteriovenous fistula | 24 | 22 |
| Carotid artery stenosis | 32 | 109 |
| Cerebral infarction (acute stage) | 51 | 203 |
| Brain tumor | 13 | 42 |
| Cerebral vasospasm | 21 | 0 |
| Others (hemorrhagic disease)** | 4 | 62 |
| Others (ischemic disease)*** | 0 | 54 |

* mean ± standard deviation
** Intracerebral hemorrhage, Subarachnoid hemorrhage, Cerebellar hemorrhage, Intraventricular hemorrhage, Subcortical hemorrhage, Subdural hemorrhage, Putaminal hemorrhage, Pontine hemorrhage
*** Cerebral infarction, Cerebellar infarction, Sinus thrombosis, Amaurosis fugax, Moyamoya disease

**Table 2 $P_{KA}$ in neuro interventional radiology (n = 288)**

| Disease | Therapeutic technique | n | (%) | $P_{KA}$ (Gy・cm$^2$) mean ± S.D. | $P_{KA}$ (Gy・cm$^2$) median [range] |
|---|---|---|---|---|---|
| Cerebral aneurysm | Coil embolization | 125 | 43 | 239 ± 77 | 235 [86—408] |
| Arteriovenous malformation | TAE | 18 | 6 | 498 ± 345 | 367 [179—1361] |
| Dural arteriovenous fistula | TAE, TVE | 24 | 8 | 349 ± 165 | 293 [177—702] |
| Carotid artery stenosis | CAS | 32 | 11 | 139 ± 39 | 125 [95—282] |
| Cerebral infarction (acute stage) | Thrombectomy | 51 | 18 | 325 ± 135 | 299 [58—625] |
| Brain tumor | TAE | 13 | 5 | 330 ± 161 | 305 [36—653] |
| Cerebral vasospasm | Intra arterial injection | 21 | 7 | 187 ± 81 | 192 [35—409] |
| Others (hemorrhagic disease) | TAE | 4 | 1 | 181 ± 46 | 170 [143—244] |
| Others (ischemic disease) | ( - ) | 0 | 0 | ( - ) | ( - ) |
| Total | | 288 | 100 | 268 ± 155 | 234 [35—1361] |

TAE: transarterial embolization, TVE: transvenous embolization, CAS: carotid artery stenting

**Table 3 $P_{KA}$ in diagnostic cerebral angiography (n = 709)**

| Disease | n | (%) | $P_{KA}$ (Gy・cm$^2$) mean±S.D. | $P_{KA}$ (Gy・cm$^2$) median [range] |
|---|---|---|---|---|
| Cerebral aneurysm | 191 | 27 | 123 ± 53 | 116 [25—385] |
| Arteriovenous malformation | 26 | 4 | 201 ± 98 | 187 [76—469] |
| Dural arteriovenous fistula | 22 | 3 | 202 ± 109 | 176 [83—485] |
| Carotid artery stenosis | 109 | 15 | 162 ± 57 | 158 [38—321] |
| Cerebral infarction (acute stage) | 203 | 29 | 179 ± 74 | 173 [43—436] |
| Brain tumor | 42 | 6 | 163 ± 68 | 147 [48—344] |
| Cerebral vasospasm | 0 | 0 | ( - ) | ( - ) |
| Others (hemorrhagic disease) | 62 | 9 | 163 ± 55 | 169 [41—300] |
| Others (ischemic disease) | 54 | 8 | 182 ± 61 | 177 [44—358] |
| Total | 709 | 100 | 161 ± 70 | 155 [25—485] |

**The Mann-Whitney test shows a significant higher values when the imaging objective was neuro IVR compared to diagnostic cerebral angiography (P < 0.01).**

**Table 4 $K_{a,r}$ in neuro interventional radiology (n = 288)**

| Disease | Therapeutic technique | n | (%) | $K_{a,r}$ (mGy) mean ± S.D. | $K_{a,r}$ (mGy) median [range] |
|---|---|---|---|---|---|
| Cerebral aneurysm | Coil embolization | 125 | 43 | 2347 ± 831 | 2280 [681—4693] |
| Arteriovenous malformation | TAE | 18 | 6 | 4928 ± 3098 | 3993 [1111—13176] |
| Dural arteriovenous fistula | TAE, TVE | 24 | 8 | 3473 ± 1485 | 3149 [1798—6766] |
| Carotid artery stenosis | CAS | 32 | 11 | 935 ± 267 | 883 [567—2027] |
| Cerebral infarction (acute stage) | Thrombectomy | 51 | 18 | 2510 ± 1032 | 2440 [710—4999] |
| Brain tumor | TAE | 13 | 5 | 2909 ± 1062 | 3001 [1332—5267] |
| Cerebral vasospasm | Intra arterial injection | 21 | 7 | 1458 ± 517 | 1400 [720—2544] |
| Others (hemorrhagic disease) | TAE | 4 | 1 | 1278 ± 389 | 1211 [883—1806] |
| Others (ischemic disease) | ( - ) | 0 | 0 | ( - ) | ( - ) |
| Total | | 288 | 100 | 2420 ± 1462 | 2179 [567—13176] |

TAE: transarterial embolization, TVE: transvenous embolization, CAS: carotid artery stenting

**Table 5 $K_{a,r}$ in diagnostic cerebral angiography (n = 709)**

| Disease | n | (%) | $K_{a,r}$ (mGy) mean±S.D. | $K_{a,r}$ (mGy) median [range] |
|---|---|---|---|---|
| Cerebral aneurysm | 191 | 27 | 875 ±379 | 838 [153—2777] |
| Arteriovenous malformation | 26 | 4 | 1408 ± 774 | 1236 [446—3319] |
| Dural arteriovenous fistula | 22 | 3 | 1403 ± 833 | 1268 [474—3598] |
| Carotid artery stenosis | 109 | 15 | 1091 ± 385 | 1061 [289—2447] |
| Cerebral infarction (acute stage) | 203 | 29 | 1251 ± 501 | 1230 [255—2892] |
| Brain tumor | 42 | 6 | 1118 ± 418 | 1061 [360—2061] |
| Cerebral vasospasm | 0 | 0 | ( - ) | ( - ) |
| Others (hemorrhagic disease) | 62 | 9 | 1078 ± 358 | 1136 [258—1958] |
| Others (ischemic disease) | 54 | 8 | 1242 ± 385 | 1179 [398—2482] |
| Total | 709 | 100 | 1112 ± 485 | 1055 [153—3598] |

**The Mann-Whitney test shows a significant higher values when the imaging objective was neuro IVR compared to diagnostic cerebral angiography (P < 0.01).**

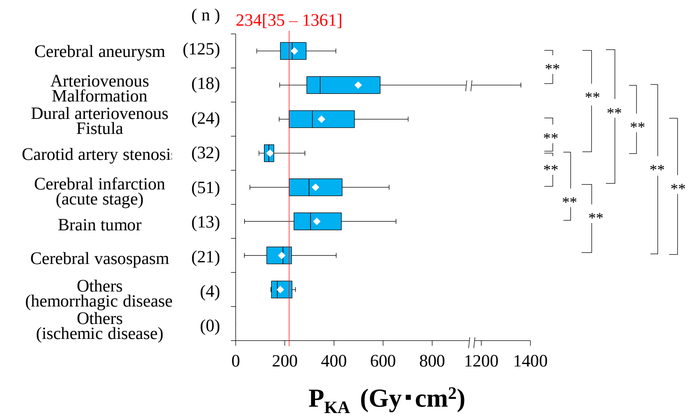



**Fig. 1 Air kerma area product ($P_{KA}$) in neuro interventional radiology (n = 288).**
*** P < 0.01, and ** P < 0.05 on the Steel-Dwass test.**

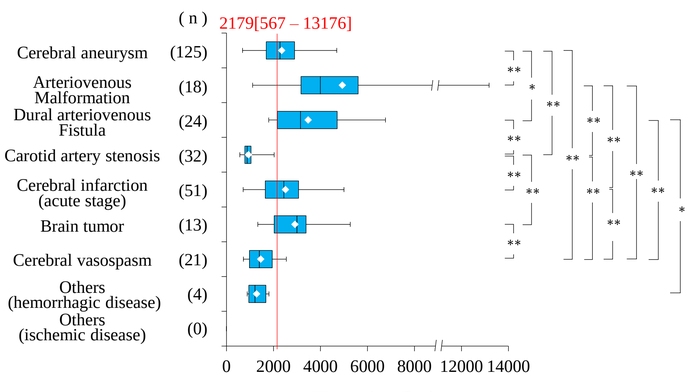



**Fig. 2 Air kerma at the patient entrance reference point ($K_{a,r}$) in neuro interventional radiology (n = 288).**
*** P < 0.01, and ** P < 0.05 on the Steel-Dwass test.**

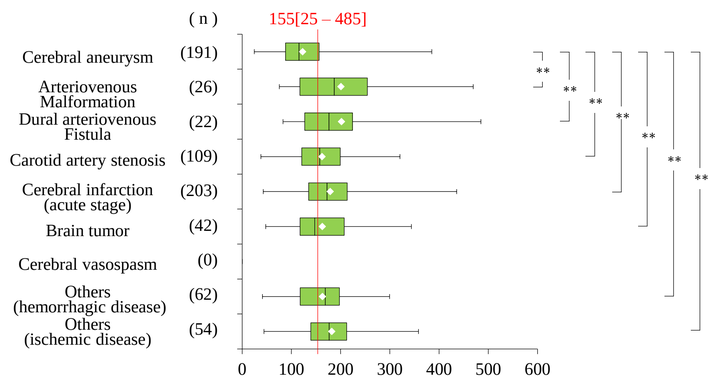



**Fig. 3 Air kerma area product ($P_{KA}$) in diagnostic cerebral angiography (n = 709).**
*** P < 0.01, and ** P < 0.05 on the Steel-Dwass test.**

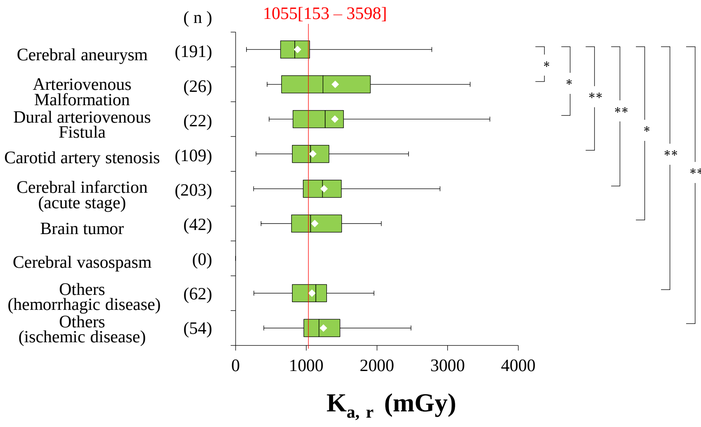



**Fig. 4 Air kerma at the patient entrance reference point ($K_{a,r}$) in diagnostic cerebral angiography (n = 709).**
*** P < 0.01, and ** P < 0.05 on the Steel-Dwass test.**

## Results

1. The $P_{KA}$ and $K_{a,r}$ of neuro IVR was significantly higher than that of diagnostic cerebral angiography (Mann-Whitney test, $P<0.01$) (Table 2, 3, 4, 5).
2. The Kruskal-Wallis test showed significant differences between the each disease group in neuro IVR and diagnostic cerebral angiography (Fig.1, 2, 3, 4).
3. Of the 28 pairwise disease combinations in neuro IVR, significant differences were found in 10 combinations for $P_{KA}$, and 15 combinations for $K_{a,r}$ (Fig. 1, 2). Of the 28 disease combinations in diagnostic angiography, significant differences were found in7 combinations for both $P_{KA}$ and $K_{a,r}$. All of them were associated with cerebral aneurysms (Fig. 3, 4).

## Discussion

1. Since there was a significant difference in exposure dose, depending on the imaging objectives (diagnostic angiography or neuro IVR), it is necessary to establish DRL for each objective.
2. In cerebral angiography, there was a significant difference for both $P_{KA}$ and $K_{a,r}$, depending on the each disease group, and it is necessary to establish DRL for each disease group.
3. In neuro IVR, there was a significant difference for both $P_{KA}$ and $K_{a,r}$ among the diseases by using the Steel-Dwass multiple comparison test. In diagnostic angiography, there was a significant difference between cerebral aneurysms and other diseases. It may be needed to study separately between preoperative and postoperative angiography, as postoperative angiography usually takes shorter time to just confirm the operative results.

Limitation: This study analyzed a relatively small sample size of data from our single institute. Currently, nationwide, multicenter research projects are progressing.

## Conclusion

In order to optimize exposure protection for various cerebral angiography, $P_{KA}$ and $K_{a,r}$ can be selected as DRL quantities, and DRL values categorized by imaging objectives and by disease groups can be established by using display value of the angiography devices.