



**Figure S1.** The personal passive dosimeter and the personal protective equipment the physicians surveyed wore in this analysis. Due to the high radiation doses of physicians, it is recommended to wear a lead apron and thyroid protection collar to reduce the risk of cancer (stochastic effect). Moreover, wearing lead glasses is recommended to avoid cataracts (tissue reaction). Japanese law stipulates the installation of the main dosimeter and the additional dosimeter as needed. The main dosimeter is to be worn inside the lead apron (male on the chest, female on the abdomen), and the additional dosimeter is to be worn outside the lead apron.



**Table S1.** Use rate of personal passive dosimeters by physicians

| Physician<br>(n = 14) | Clinical department | Number of visual inspection |                     |                             | Main dosimeter (under lead apron) |              |                      |              |                             | Additional dosimeter (over lead apron) |              |                      |              |                             |
|-----------------------|---------------------|-----------------------------|---------------------|-----------------------------|-----------------------------------|--------------|----------------------|--------------|-----------------------------|--|--------------|----------------------|--------------|-----------------------------|
|                       |                     |                             |                     | <i>p</i> value <sup>†</sup> | Pre-intervention period           |              | Intervention period  |              | <i>p</i> value <sup>†</sup> | Pre-intervention period                |              | Intervention period  |              | <i>p</i> value <sup>†</sup> |
|                       |                     | Pre-intervention period     | Intervention period |                             | Number of times used              | Use rate (%) | Number of times used | Use rate (%) |                             | Number of times used                   | Use rate (%) | Number of times used | Use rate (%) |                             |
| a, M                  | Neurosurgery        | 14                          | 10                  |                             | 9                                 | 64           | 9                    | 90           |                             | 9                                      | 64           | 9                    | 90           |                             |
| b, M                  | Neurosurgery        | 36                          | 29                  |                             | 27                                | 75           | 29                   | 100          |                             | 27                                     | 75           | 29                   | 100          |                             |
| c, M                  | Neurosurgery        | 41                          | 4                   |                             | 18                                | 44           | 4                    | 100          |                             | 18                                     | 44           | 4                    | 100          |                             |
| d, M                  | Internal Medicine   | 32                          | 39                  |                             | 19                                | 59           | 39                   | 100          |                             | 19                                     | 59           | 39                   | 100          |                             |
| e, M                  | Cardiology          | 35                          | 18                  |                             | 25                                | 71           | 18                   | 100          |                             | 25                                     | 71           | 18                   | 100          |                             |
| f, M                  | Internal Medicine   | 60                          | 38                  |                             | 60                                | 100          | 38                   | 100          |                             | 60                                     | 100          | 38                   | 100          |                             |
| g, M                  | Endocrinology       | 3                           | 3                   |                             | 0                                 | 0            | 2                    | 67           |                             | 0*                                     | 0*           | 2**                  | 67**         |                             |
| h, M                  | Orthopedic surgery  | 16                          | 3                   |                             | 1                                 | 6            | 3                    | 100          |                             | 0*                                     | 0*           | 3**                  | 100**        |                             |
| i, M                  | Orthopedic surgery  | 92                          | 75                  |                             | 15                                | 16           | 73                   | 97           |                             | 0*                                     | 0*           | 59**                 | 79**         |                             |
| j, M                  | Orthopedic surgery  | 58                          | 72                  |                             | 46                                | 79           | 72                   | 100          |                             | 0*                                     | 0*           | 53**                 | 74**         |                             |
| k, M                  | General Surgery     | 9                           | 22                  |                             | 1                                 | 11           | 22                   | 100          |                             | 0*                                     | 0*           | 0*                   | 0*           |                             |
| l, M                  | General Surgery     | 14                          | 19                  |                             | 2                                 | 14           | 19                   | 100          |                             | 0*                                     | 0*           | 0*                   | 0*           |                             |
| m, M                  | Urology             | 9                           | 18                  |                             | 5                                 | 56           | 18                   | 100          |                             | 0*                                     | 0*           | 0*                   | 0*           |                             |
| n, F                  | Urology             | 5                           | 15                  |                             | 3                                 | 60           | 15                   | 100          |                             | 0*                                     | 0*           | 0*                   | 0*           |                             |
| Mean ± SD             |                     | 30.3 ± 25.8                 | 26.1 ± 23.1         | 0.382                       | 16.5 ± 18.2                       | 47 ± 32      | 25.8 ± 22.9          | 97 ± 9       | 0.002                       | 11.3 ± 17.4                            | 30 ± 37      | 18.1 ± 21.3          | 65 ± 44      | 0.008                       |
| Median [range]        |                     | 24 [3–92]                   | 18.5 [3–75]         |                             | 12 [0–60]                         | 57 [0–100]   | 18.5 [2–73]          | 100 [67–100] |                             | 0 [0–60]                               | 0 [0–100]    | 6.5 [0–59]           | 85 [0–100]   |                             |

SD: standard deviation  
M: Male  
F: Female  
\* Under the operation with single-dosimeter approach  
\*\* Switched management method from single-dosimeter to double-dosimeter approach during intervention period  
† Wilcoxon's signed rank test.

Table S2. The use rate of personal protective equipment (PPE) by physicians

| Physician<br>(n = 14) | Clinical<br>department | Number of visual inspections |                     |                             | Lead apron              |              |                         |              |                             | Lead glasses            |              |                         |              |                             | Thyroid protection collar |              |                     |              |                             |
|-----------------------|------------------------|------------------------------|---------------------|-----------------------------|-------------------------|--------------|-------------------------|--------------|-----------------------------|-------------------------|--------------|-------------------------|--------------|-----------------------------|---------------------------|--------------|---------------------|--------------|-----------------------------|
|                       |                        | Pre-intervention period      | Intervention period | <i>p</i> value <sup>†</sup> | Pre-intervention period |              | Intervention period     |              | <i>p</i> value <sup>†</sup> | Pre-intervention period |              | Intervention period     |              | <i>p</i> value <sup>†</sup> | Pre-intervention period   |              | Intervention period |              | <i>p</i> value <sup>†</sup> |
|                       |                        |                              |                     |                             | Number of<br>times used | Use rate (%) | Number of<br>times used | Use rate (%) |                             | Number of<br>times used | Use rate (%) | Number of<br>times used | Use rate (%) |                             | Number of<br>times used   | Use rate (%) |                     |              |                             |
|                       |                        |                              |                     |                             |                         |              |                         |              |                             |                         |              |                         |              |                             |                           |              |                     |              |                             |
| a, M                  | Neurosurgery           | 14                           | 10                  |                             | 14                      | 100          | 10                      | 100          |                             | 13                      | 93           | 10                      | 100          |                             | 13                        | 93           | 9                   | 90           |                             |
| b, M                  | Neurosurgery           | 36                           | 29                  |                             | 36                      | 100          | 29                      | 100          |                             | 33                      | 92           | 29                      | 100          |                             | 35                        | 97           | 28                  | 97           |                             |
| c, M                  | Neurosurgery           | 41                           | 4                   |                             | 41                      | 100          | 4                       | 100          |                             | 30                      | 73           | 4                       | 100          |                             | 39                        | 95           | 4                   | 100          |                             |
| d, M                  | Internal Medicine      | 32                           | 39                  |                             | 32                      | 100          | 39                      | 100          |                             | 9                       | 28           | 39                      | 100          |                             | 32                        | 100          | 39                  | 100          |                             |
| e, M                  | Cardiology             | 35                           | 18                  |                             | 35                      | 100          | 18                      | 100          |                             | 3                       | 9            | 18                      | 100          |                             | 29                        | 83           | 16                  | 89           |                             |
| f, M                  | Internal Medicine      | 60                           | 38                  |                             | 60                      | 100          | 38                      | 100          |                             | 58                      | 97           | 38                      | 100          |                             | 60                        | 100          | 38                  | 100          |                             |
| g, M                  | Endocrinology          | 3                            | 3                   |                             | 3                       | 100          | 3                       | 100          |                             | 3                       | 100          | 2                       | 67           |                             | 3                         | 100          | 3                   | 100          |                             |
| h, M                  | Orthopedic surgery     | 16                           | 3                   |                             | 16                      | 100          | 3                       | 100          |                             | 0                       | 0            | 3                       | 100          |                             | 0                         | 0            | 3                   | 100          |                             |
| i, M                  | Orthopedic surgery     | 92                           | 75                  |                             | 92                      | 100          | 75                      | 100          |                             | 0                       | 0            | 75                      | 100          |                             | 0                         | 0            | 75                  | 100          |                             |
| j, M                  | Orthopedic surgery     | 58                           | 72                  |                             | 58                      | 100          | 72                      | 100          |                             | 13                      | 22           | 72                      | 100          |                             | 2                         | 3            | 72                  | 100          |                             |
| k, M                  | General Surgery        | 9                            | 22                  |                             | 9                       | 100          | 22                      | 100          |                             | 0                       | 0            | 21                      | 95           |                             | 0                         | 0            | 21                  | 96           |                             |
| l, M                  | General Surgery        | 14                           | 19                  |                             | 14                      | 100          | 19                      | 100          |                             | 0                       | 0            | 17                      | 89           |                             | 0                         | 0            | 17                  | 90           |                             |
| m, M                  | Urology                | 9                            | 18                  |                             | 9                       | 100          | 18                      | 100          |                             | 0                       | 0            | 18                      | 100          |                             | 5                         | 56           | 18                  | 100          |                             |
| n, F                  | Urology                | 5                            | 15                  |                             | 5                       | 100          | 15                      | 100          |                             | 0                       | 0            | 15                      | 100          |                             | 0                         | 0            | 15                  | 100          |                             |
| Mean ± SD             |                        | 30.3 ± 25.8                  | 26.1 ± 23.1         |                             | 30.3 ± 25.8             | 100 ± 0      | 26.1 ± 23.1             | 100 ± 0      |                             | 11.6 ± 17.4             | 37 ± 43      | 25.8 ± 23.3             | 97 ± 9       |                             | 15.6 ± 19.7               | 52 ± 48      | 25.6 ± 23.3         | 97 ± 4       |                             |
| Median [range]        |                        | 24 [3–92]                    | 18.5 [3–75]         | 0.382                       | 24 [3–92]               | 100          | 18.5 [3–75]             | 100          | 1.000                       | 3 [0–58]                | 15 [0–100]   | 18 [2–75]               | 100 [67–100] | 0.003                       | 4 [0–60]                  | 69 [0–100]   | 17.5 [3–75]         | 100 [89–100] | 0.008                       |

SD: standard deviation

M: Male

F: Female

<sup>†</sup> Wilcoxon's signed rank test.



**Table S3.** Personal exposure dose and dose rate of physicians

| Physician<br>(n = 14) | Clinical department | Number of radiation medical treatments<br>conducted |                        |                             | Total fluoroscopy time (min) |                        |                              | Effective dose (mSv)       |                        |                             | Effective dose rate (µSv/min) |                        |                             | Lens equivalent dose (mSv) |                        |                             | Lens equivalent dose rate (µSv/min) |                        |                             |
|-----------------------|---------------------|---|------------------------|-----------------------------|------------------------------|------------------------|------------------------------|----------------------------|------------------------|-----------------------------|-------------------------------|------------------------|-----------------------------|----------------------------|------------------------|-----------------------------|-------------------------------------|------------------------|-----------------------------|
|                       |                     |   |                        |                             | (a)                          |                        |                              | (b)                        |                        |                             | (b/a)                         |                        |                             | (c)                        |                        |                             | (c/a)                               |                        |                             |
|                       |                     | Pre-intervention<br>period                          | Intervention<br>period | <i>p</i> value <sup>†</sup> | Pre-intervention<br>period   | Intervention<br>period | <i>p</i> value <sup>††</sup> | Pre-intervention<br>period | Intervention<br>period | <i>p</i> value <sup>†</sup> | Pre-intervention<br>period    | Intervention<br>period | <i>p</i> value <sup>†</sup> | Pre-intervention<br>period | Intervention<br>period | <i>p</i> value <sup>†</sup> | Pre-intervention<br>period          | Intervention<br>period | <i>p</i> value <sup>†</sup> |
| a, M                  | Neurosurgery        | 22  | 15                     |                             | 259.8                        | 238.0                  |                              | 0.3                        | 0.4                    |                             | 1.2                           | 1.7                    |                             | 0.7                        | 0.9                    |                             | 2.7                                 | 3.8                    |                             |
| b, M                  | Neurosurgery        | 56  | 36                     |                             | 1027.7                       | 957.6                  |                              | 1.4                        | 1.3                    |                             | 1.4                           | 1.4                    |                             | 7.5                        | 7.8                    |                             | 7.3                                 | 8.1                    |                             |
| c, M                  | Neurosurgery        | 57  | 5                      |                             | 1041.7                       | 116.1                  |                              | 0.4                        | 0.1                    |                             | 0.4                           | 0.9                    |                             | 1.0                        | 0.8                    |                             | 1.0                                 | 6.9                    |                             |
| d, M                  | Internal Medicine   | 57  | 48                     |                             | 946.8                        | 643.4                  |                              | 1.1                        | 4.0                    |                             | 1.2                           | 6.2                    |                             | 2.0                        | 7.1                    |                             | 2.1                                 | 11.0                   |                             |
| e, M                  | Cardiology          | 52  | 23                     |                             | 1926.7                       | 647.3                  |                              | 3.2                        | 1.0                    |                             | 1.7                           | 1.5                    |                             | 7.3                        | 3.6                    |                             | 3.8                                 | 5.6                    |                             |
| f, M                  | Internal Medicine   | 108   | 67                     |                             | 2901.5                       | 934.1                  |                              | 6.3                        | 4.8                    |                             | 2.2                           | 5.1                    |                             | 23.7                       | 13.9                   |                             | 8.2                                 | 14.9                   |                             |
| g, M                  | Endocrinology       | 4   | 6                      |                             | 231.5                        | 274.6                  |                              | 0.4                        | 0.5                    |                             | 1.7                           | 1.8                    |                             | 0.4                        | 1.7                    |                             | 1.7                                 | 6.2                    |                             |
| h, M                  | Orthopedic surgery  | 19  | 3                      |                             | 18.0                         | 2.8                    |                              | 0.0                        | 0.0                    |                             | 0.0                           | 0.0                    |                             | 0.0                        | 0.1                    |                             | 0.0                                 | 35.7                   |                             |
| i, M                  | Orthopedic surgery  | 118   | 77                     |                             | N/A                          | 97.6                   |                              | 0.0                        | 3.2                    |                             | 0.0                           | 32.8                   |                             | 0.0                        | 12.0                   |                             | 0.0                                 | 123.0                  |                             |
| j, M                  | Orthopedic surgery  | 100   | 53                     |                             | 88.2                         | 45.5                   |                              | 1.2                        | 1.5                    |                             | 13.6                          | 33.0                   |                             | 1.4                        | 7.6                    |                             | 15.9                                | 167.0                  |                             |
| k, M                  | General Surgery     | 23  | 44                     |                             | 267.3                        | 348.1                  |                              | 0.1                        | 1.5                    |                             | 0.4                           | 4.3                    |                             | 0.1                        | 1.6                    |                             | 0.4                                 | 4.6                    |                             |
| l, M                  | General Surgery     | 35  | 30                     |                             | 307.5                        | 146.7                  |                              | 0.2                        | 1.1                    |                             | 0.7                           | 7.5                    |                             | 0.2                        | 1.2                    |                             | 0.7                                 | 8.2                    |                             |
| m, M                  | Urology             | 18  | 21                     |                             | 135.6                        | 129.1                  |                              | 0.6                        | 0.4                    |                             | 4.4                           | 3.1                    |                             | 0.6                        | 0.4                    |                             | 4.4                                 | 3.1                    |                             |
| n, F                  | Urology             | 8   | 18                     |                             | 30.5                         | 129.2                  |                              | 0.1                        | 0.4                    |                             | 3.3                           | 3.1                    |                             | 0.1                        | 0.4                    |                             | 3.3                                 | 3.1                    |                             |
| Mean ± SD             |                     | 48.4 ± 37.4   | 31.9 ± 23.3            | 0.030                       | 706.4 ± 865.9                | 336.4 ± 324.8          | 0.344                        | 1.1 ± 1.7                  | 1.4 ± 1.5              | 0.345                       | 2.3 ± 3.5                     | 7.3 ± 11.0             | 0.033                       | 3.2 ± 6.4                  | 4.2 ± 4.6              | 0.124                       | 3.7 ± 4.3                           | 28.7 ± 50.7            | 0.003                       |
| Median [range]        |                     | 43.5 [4–118]  | 26.5 [3–77]            |                             | 267.3 [18.0–2901.5]          | 192.4 [2.8–957.6]      |                              | 0.4 [0.0–6.3]              | 1.1 [0.0–4.8]          |                             | 1.3 [0.0–13.6]                | 3.1 [0.0–33.0]         |                             | 0.7 [0.0–23.7]             | 1.7 [0.1–13.9]         |                             | 2.4 [0.0–15.9]                      | 7.5 [3.1–167.0]        |                             |

SD: standard deviation

M: Male

F: Female

N/A: not available

<sup>†</sup> Wilcoxon's signed rank test

<sup>††</sup> Mann-Whitney's U test.