Radiation Exposure during Cerebral Artery Aneurysm Coil Embolization: the Current Situation and Measures to Prevent Radiation Injury

T. SHOHJI, T. ISHIBASHI*, Y. MURAYAMA*, T. SAGUCHI*, M. EBARA*, K. IRIE*, H. TAKAO**, T. ABE**

Department of Radiology, JIKEI University School of Medicine

*Department of Neurosurgery, JIKEI University School of Medicine

**Division of Endovascular Neurosurgery, Department of Neurosurgery, JIKEI University School of Medicine

Key words: radiation injury, temporary alopecia, exposure reduction

Summary

Coil embolization is the treatment of choice for cerebral artery aneurysms at our institution. The duration of a fluoroscopic study and frequency of radiation exposure are varied, and the safety measures against radiation injury have not yet been established. Guidelines about radiation injury prevention with IVR have been published. However, there is not yet a detailed report for the head region. We also report our measures to try to reduce the amount of radiation exposure during the embolization procedure in our institution.

Introduction

Coil embolization is the treatment of choice for the cerebral artery aneurysm at our institution. However, the duration of a fluoroscopic study and frequency of radiation exposure are varied, and the safety measures against radiation injury have not yet been established. At present, the radiation exposure is controlled by an area dosimeter attached to the angiographic system. In reality, however, we are only measuring the estimate of output dosages and effective utilization of the area dosimeter has not been achieved. Moreover, temporary alopecia due to radiation injury has been observed in several

cases, and it is thought that a plan of the radiation exposure management and drafting of radiation exposure reduction measures are necessary. This study reports the current situation of radiation exposure during cerebral aneurysm coil embolization by using a Radioactivity distribution map and by plotting a graph to demonstrate change of Radiation dosage during the procedure. We also report our measures to try to reduce the amount of radiation exposure during the embolization procedure.

Methods

Aims of this study were to understand the current situation of radiation exposure during the cerebral aneurysm coil embolization and to establish appropriate measures to reduce the amount of radiation exposure to prevent radiation injury. The following experiments were performed.

1) Radiation Exposure Dosimetry

Figure 1 shows the experimental apparatus. A 20 cm-thick acrylic board was placed so that the distance between it and FPD was 10 cm. SID was set to be 100 cm. In order to understand the basic properties of the apparatus, the following items were evaluated for each inch and each mode.

Figure 1 Basic characteristic of radiation exposure dosimetry.

a) Dose rate change during fluoroscopy as the acryl board-FPD distance was changed, while SSD was fixed at 70 cm.

b) Dose rate change during fluoroscopy as the SID was changed, while the acryl board-FPD distance was fixed.

c) Dose rate change during fluoroscopy as the acryl board-FPD distance was changed, while SID was fixed at 100 cm.

d) Dose rate change during fluoroscopy as the exposure field was decreased.

e) Radiation exposure dosimetry in each region of 3D rotation radiography.

II) Radiation dose distribution map

A number map was constructed by placing improved markers at 5 cm intervals on a film 14x17 inch in size (figure 2A). This enabled more accurate analysis of dose distribution using interpolation (figure 2B). This sheet was placed to wrap around a dummy head (figure 2C). And I made a dose of radiation activity distribution map was constructed based on a

value of markers and the area dosimeter which appeared on a screen.

III) Plotting a graph of change in radiation dose versus time

Advantages of an area dosimeter are that it enables us to easily grasp a radiation dose and to always understand the total radiation exposure dose.

Figure 3 shows a graph where a total radiation dose from the area dosimeter was plotted on the vertical axis and time elapsed between room entry and removal of catheter (i.e. the end of procedure). Values were noted at points (I to II) specified in the standard protocol for the cerebral aneurysm coil embolization at our institution.

Results

I) Radiation exposure dosimetry

Measurement results for each geometry is shown in figures 4 to 8.

Figure 2 About radiation dose distribution map. A) The number map which it made with oneself. B) A way of thinking of the number map. C) How to spread the number map.

Standard protocol

- 1 Room entry
- 2 Femoral puncture
- 3 Main vessel radiography
- 4 1st 3D rotation radiography
- 5 Decide a working angle
- 6 The 1st coil embolization end
- 7 The coil embolization end
- 8 2nd 3D rotation radiography
- 9 Another vessel radiography
- 10 Dyna-CT
- 11 Removal of catheter

Figure 3 Plotting a graph of change in radiation dose versus time A) A standard protocol for aneurysm treatment of our institution. B) I made a time radiation exposure dose of change graph by note a value in the same point of I to II with a Excel.

Figure 4 Dose rate change during fluoroscopy as the acryl board- FPD distance was changed, while SSD was fixed at 70 cm.

Figure 5 Dose rate change during fluoroscopy as the SID was changed, while the acryl board- FPD distance was fixed.

Figure 6 Dose rate change during fluoroscopy as the acryl board- FPD distance was changed, while SID was fixed at 100 cm.

Figure 7 Dose rate change during fluoroscopy as the exposure field was decreased.

	3D rotation radiography	Dyna-CT
Rotation Angle	190°	220°
Field Size	48cm	48cm
X-ray Condition	70kV,250mA,10ms	85kV,200mA,10ms
Scan Time	6sec	20sec
Back of the head	71.7mGy	229.4mGy
Right temporal bone	30.8mGy	123.4mGy
Left temporal bone	35.8mGy	158.1mGy
Head center	12.3mGy	60.7mGy
Left lens	10.2mGy	68.6mGy
Thyroid	2.1mGy	30mGy

Figure 8 Radiation exposure dosimetry in each region of 3D rotation radiography.

II) The case analysis result used a radiation dose distribution map plotting a graph of change in radiation dose versus time.

Coil embolization was performed to treat an aneurysm located at Lt-IC top and Lt-ICPC. There is another aneurysm at Rt-BA-SCA (figure 9A,B).

Figure 9C summarizes the total duration of fluoroscopic procedure and total amount of radiation exposure during the procedure.

Figure 10A shows a working angle and photographs of Lt-IC top aneurysm and figure 10B shows a working angle and photographs of Lt-ICPC aneurysm.

Radiation dose distribution map during coil embolization procedure for the aneurysm at Lt-IC top is shown in figure 11A and, that for the aneurysm at Lt-ICPC is shown in figure 11B and the final dose distribution is shown in figure 12A.

Figure 13 shows variation of radiation dose against time throughout the procedures.

Discussion

As shown in figure 4, radiation exposure dose increases when radiation field size is increased. In addition, the longer the distance between FPD and the acrylic board, the larger the radiation exposure dose. Therefore, it is always important to keep this distance short. As figure 5 shows, radiation exposure dose decreases when SID is increased. The reason for this seems to be that, although the X-ray output increases as SID is increased, due to an associated increase in the distance between the X-ray tube and the acrylic board, the influence of soft rays is also reduced. As the acryl-FPD distance increases, radiation dose also increases as shown in figure 6. Similar graphs were obtained in figure 4, where the increase in radiation dose was due to increase in output of the device because of increased SID. However, in case of figure 6, the increase in radiation dose resulted from increased influence from soft rays due to

Figure 9 bout patient and treatment information. A,B) There is another aneurysm at Lt-IC top and Lt-ICPC and Rt-BA-SCA by CT-Angio. C) The total duration of fluoroscopic procedure and total amount of radiation exposure during the procedure.

Figure 10 Working angle and photograph. A) Working angle and photograph of Lt-IC top aneurysm. B) Working angle and photograph of Lt-ICPC aneurysm.

Figure 11 Radiation dose distribution map. A) Radiation dose distribution map during coil embolization procedure for the aneurysm at Lt-IC top. B) Radiation dose distribution map during coil embolization procedure for the aneurysm at Lt-ICPC.

Figure 12 About the final dose distribution map. A) The final dose distribution map. B) Fusion with a real photograph revealed presence of a hotspot.

Figure 13 Variation of radiation dose against time throughout the procedures.

increased acryl-FPD distance and decreased acryl-X-ray tube distance, when SID was fixed. Additionally, recent shift from the use of I.I. to FPD at our institution resulted in a change in shape of radiation field, as well as a slight increase in the size of hotspot. Therefore it was necessary to pay attention to change in radiation dose when decreasing the size of radiation field. Further, a large change in radiation dose was observed when the field was reduced by more than 5 cm from the periphery at FPD of 16cm. Figure 8 shows radiation dose at each photographic angle in each region. Recently, 3D rotational photography became essential in treatment planning and improvement of therapeutic results. However, sufficient amount of consideration for radiation dose and its need should be given before performing the procedure. In the present case, the total radiation dose was 5,240 mGy, but radiation dose distribution was dispersed because attempts were made to treat two aneurysms. The final dose distribution these is shown in figure 12A and the hotspot was 3,990 mGy. Fusion with a real

photograph revealed presence of a hotspot, approximately 2.5 cm wide, near the back of head (figure 12B). This elongated shape is thought to be caused by overlap of radiation fields of working angle for each aneurysm. It is thought that this could be prevented if radiation field was reduced while being careful about change of radiation dose, or alter working angles a little without interfering with the procedure itself, or apply a framing that considered repetition beforehand. And figure 13 shows a graph of change in radiation dose versus time.

It is possible to grasp an approximate total radiation dose during each treatment by using these graphs. From this graph, one can see the front X-ray tube was mainly used for treatment. Also, performing coil embolization using balloon assistance to treat those wide-necked aneurysms lead to increase in fluoroscopic radiation doses from the front tube, in comparison with a total dose while taking X-ray photos. Figures 14 and 15 show radiation injuries following IVR procedures and general methods to reduce radiation exposure. It is not always

Region	Indication	Threshold	Time of presentation
Skin	Temporary erythema	2Gy	2~24hour
	Temporary alopecia	3Gy	Less than 3week
	Permanent alopecia	7Gy	Less than 3week
Eye	Lens opacification	More than 1~2Gy	More than 5year
	Cataract	More than 5Gy	More than 5year

Figure 14 Radiation injury in a head region.

- Avoid unnecessary fluoroscopic and photographic dose.
- Avoid unnecessary "inch-up".
- Use minimum fluoroscopic
and photographic frame setting.
- Decrease the size of exposure field to a minimum.
- Use an additional filter.
- Separate X-ray tube from the subject as much as possible.
- Minimize the distance between the subject and FPD.
- Preferentially bring forward the FPD of main X-ray tube.
- Grasp a radiation dose of each mode.

Figure 15 General radiation exposure reduction measures.

After working angle decision,

So as not to influence the treatment,
the catheter table is raised as much as possible.

FPD(a) that becomes a main as much as possible is brought close.

The other FPD(b) is brought close as much as possible.

The angle of the FPD(b) is changed a little if it cannot be
brought close enough because of the position of the other tube.

Each exposure field is decreased as much as possible.

Figure 16 Ideal radiation exposure reduction measures in our institution.

possible to keep all of these in mind while performing a procedure. Therefore, we thought that it would be more effective to achieve reduction in radiation exposure during coil embolization procedure, which is performed after determination of working angle following a study of a graph of change in radiation dose versus time. In addition, it can be said that both a dose during fluoroscopy and that while taking photographs change remarkably at the time of coil embolization from a graph of change in radiation dose versus time. Therefore, we suggest measures shown in figure 16. We believe these measures will limit the degree of radiation field overlap to a minimum and also minimize the radiation exposure within the limited geometry.

Conclusions

In recent years various images came to be provided by progress of angiographic systems. However, the acquisition of a high-grade image and optimum settings for X-ray fluoroscopic and photographic condition do not always lead to improvement in therapeutic results. Know-

ing actual interventional procedures well and choosing optimum settings for each therapy, while understanding radiation dose for each setting, is of paramount importance to radiographers. Therefore the first step to reduce medical radiation exposure for patients is to gain sufficient knowledge and understanding about various X-ray systems and keep ourselves up-to-date with technological progress.

References

- 1 Avoidance of Radiation Injuries from Medical Interventional Procedures. ICRP Publication 85. Japan 2003.
- 2 A guideline about radiation skin injury prevention with IVR.Q&A and explanation. JARPM, 2004.

Tomokazu Shohji, M.D.
3-25-8 Nishi-shinbashi, Minato- Ku
Tokyo 105-8461 Japan
E-mail: t_shohuji@jikei.ac.jp