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We applaud the efforts of Moskowitz et al to increase awareness of the risks of cumulative radiation dose in their article, "Cumulative Radiation Dose during Hospitalization for Aneurysmal Subarachnoid Hemorrhage."[1] We certainly agree that it is essential to minimize radiation dose from all sources because the diagnosis and treatment of patients with subarachnoid hemorrhage may result in a substantial radiation exposure from multiple sources. At the same time, we were surprised at the magnitude of cumulative radiation doses reported. These are beyond those expected on the basis of the literature and our own experience. We believe that there are several contributing factors for these discrepancies.

There are 2 general types of radiation injuries: deterministic and stochastic. These need to be accounted for separately. In neuroradiology, the main organs susceptible to deterministic injury are the skin and the lens of the eyes. Skin erythema will generally be evident at 6–8 Gy. Doses exceeding 8 Gy will result in exudative and erosive changes to the skin, and doses exceeding 20 Gy will result in nonhealing ulceration.[2,3] Temporary epilation will occur at 3–5 Gy, and permanent epilation, at single doses exceeding 7 Gy.[2] Not all body areas are equally sensitive; however, the scalp and beard are among the most sensitive to radiation epilation. Irradiation of the eye will lead to cataract formation for single doses of 2 Gy and fractionated doses of 4 Gy.[3,4] The stochastic effects refer to the formation of future cancers. In this article, the authors refer to the cranial dose; we presume that the authors in fact are referring to the entrance skin dose.

In calculating and reporting the absorbed dose to the skin (an organ dose), one typically is interested in the peak dose to any 1 location on the skin. It is assumed that this region of peak exposure is the most likely to demonstrate injury. Maintaining that region at the lowest possible dose will, in general, reduce the severity of injury. One must, therefore, consider the orientation of the beam relative to the patient in such calculations. The relative skin dose at the entrance and exit surfaces of the patient typically varies by a factor of 30–100 in radiography and fluoroscopy. In CT scans, the skin dose is, to a first approximation, constant over all irradiated regions of the skin. In this article, the authors implicitly assume that the region of the skin exposed to the peak radiation in each procedure is the same and, thus, that the cumulative skin dose is equal to the sum of the procedural entrance skin doses; this is clearly an overestimation.

The result shown in this article for the mean cumulative radiation dose given to the cranium during the course of hospitalization was 12.8 ± 7.7 Gy (range, 2.4–36.1 Gy). This is a surprising number, especially because the authors report that even the patients who went to open surgical aneurysm clipping with no intervention accumulated doses in the 4 Gy range. Presuming a mathematic error, we recalculated the dose for patients without intervention from the data pro-

vided in the article. The Table is based on the doses indicated in their "Equipment and Radiation Dose" section of the article. We used their projected dose from C-arm intraoperative angiography alone because the authors indicate that routine digital subtraction angiography (DSA) was not part of their treatment algorithm. This rough approximation indicates that the result published in the article for this group (average, 4.6 Gy) is significantly higher than the estimated cumulative dose (1.2 Gy).

We have additional concerns with this work. The article does not indicate the neurointerventional procedure dose from the biplane Axiom Artis dBA scanner (Siemens, Erlangen, Germany) but does state the dose by using a Siemens portable C-arm (Siremobil Iso-C). This dose of 310 mGy seems much higher than expected. The dose will depend on many factors, such as collimation, kilovolt, and milliampere settings and the magnification setting, which are not indicated in the article. If we assume a 1 R/min fluoroscopy rate and 100 mR/frame for the acquisition mode, then the dose for this procedure would be more like 90 mGy compared with 310 mGy.

Because the authors indicate that 87% of the cumulative dose could be accounted for by the neurointerventions, one would expect that their experience could be benchmarked against other studies of radiation exposure during similar interventions. A study from 2007 by D'Ercole et al[5] not only used the air kerma values but validated them against readings from a Gafchromic film (ISP, Wayne, New Jersey) placed on that patient. In their study of 21 procedures, the maximum absorbed dose was 3.20 Gy with mean of 1.1 Gy. Even assuming that all the patients in the article by Moskowitz et al had even more complex procedures, as the authors suggested, it is difficult to understand how their patients experienced doses that were 10-fold higher.

Because no comparative reference dosimetry method was used for the study of Moskowitz et al, it seems most likely that the numbers reported are misinterpreted or misrepresented by the equipment as the authors of the Moskowitz paper themselves suggest. Adding support to this premise, the unit used to indicate cumulative dose that was correlated with length of hospitalization in Fig 5 is milligray, while Figs 3 and 4 use gray for the same patients. The absence of any reports of acute radiation injury in their patient population does not support the authors conclusions since at the doses cited, most of their patients should have demonstrated substantial skin injuries and cataract formation, depending on the proximity and/or inclusion of the orbits in the radiation field.

We think that is it important that the authors review their calculations and validate their equipment against another standard. If their patients are indeed receiving such doses, the authors should re-evaluate their interventional techniques. While the cumulative doses of CT, CT perfusion, and CT angiography (CTA) in addition to DSA and neurointervention can approach 3 Gy in some patients, we do not think that the high doses reported in this article are representative of the average radiation dose in this patient group. If this proves to be an overestimation, it illustrates the difficulties that may be encountered when using estimated doses and highlights the speculative nature of some articles that use dose estimates instead of the measured radiation dose.

Estimated dose for patients without intervention

Modality	Mean No. of Procedures/Case	mGy/Case	Total Dose
Angiography	1.2	310	372.0
Head CT	2.9	46.4	134.6
Portable CT	4.0	120	480.0
CTA	1.5	46.4	69.6
CT perfusion	0.6	288.7	173.2
Chest x-ray	12.0	Negligible	Negligible
		Cumulative dose (mGy)	1229.4
		Cumulative dose (Gy)	1.2

References

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