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Radiation Exposure from Conventional and Digital Subtraction Angiography of Cerebral Vessels

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Patients with atherosclerotic cerebrovascular disease were studied to determine the radiation exposure associated with conventional and digital subtraction angiography of the cerebral vessels. The median exposure-area product was 3198 R cm² (range, 616–5665 R cm²) in the conventional angiography group and 1831 R cm² (range, 366–4198 R cm²) in the IV digital subtraction angiography (DSA) group. This difference in exposure resulted from increased use of fluoroscopy in the conventional screen-film angiography group. The actual difference in exposure between the radiographic and digital imaging portions of the examinations was much smaller. The contributions of fluoroscopy to the radiation exposure in conventional angiography and IV-DSA in this study were 37% (range, 8.8–76%) and 6% (range, 1.5–25%), respectively.

The introduction of digital subtraction angiography (DSA) with either intravenous (IV) or intraarterial (IA) injection of contrast medium has added a new dimension to cerebral angiography. IV-DSA is a noninvasive imaging technique that can be performed rapidly on an outpatient basis at relatively low cost [1–4]. Compared with conventional screen-film methods, IA-DSA offers several advantages: less contrast medium is required, there is less need for selective arterial catheterization, examination time is shortened, subtracted images are immediately available, and film costs are reduced [5, 6].

DSA also has the potential advantage of reducing the amount of radiation the patient is exposed to, as noted by Pavlicek et al. [7]. Their results indicated reduction of radiation exposure to the bone marrow and lens of the eye by a factor of $1/20$ and reduction of exposure to the thyroid by a factor of $1/10$ with IV-DSA as compared with conventional screen-film angiography of the carotid vessels. They attributed this decrease to the use of smaller field sizes and less fluoroscopy time.

In considering the effects of radiation exposure on a patient, one must take into account how much of the patient's body is being irradiated. Although delivery of a single dose of 100–300 rads of whole-body radiation would result in an acute radiation syndrome, delivery of 4000 rads or more to carefully shielded areas of the patient undergoing radiotherapy is often achieved with no fatal outcome [8]. Measurements of radiation exposure at the entry portal do not take into account the area exposed. Therefore, we decided to measure patient radiation exposure in terms of exposure-area product. This unit, which is expressed in roentgens \times centimeters squared (R cm²) more closely approximates the actual dose absorbed by the patient because it takes into account the amount of the body irradiated as well as the entrance radiation exposure.

The concept of exposure-area product (EAP) or roentgen-area product (RAP) was first introduced in the late 1950s. In 1964, Pychlau and Bunde [9] demonstrated experimentally that, in the diagnostic energy range, the EAP is proportional to the energy absorbed by the patient. Harrison [10] and Shrimpton and Wall [11] demonstrated rigorously that the EAP can be used to determine the energy imparted to the patient with accuracies of 5–10%. The integral dose (or energy

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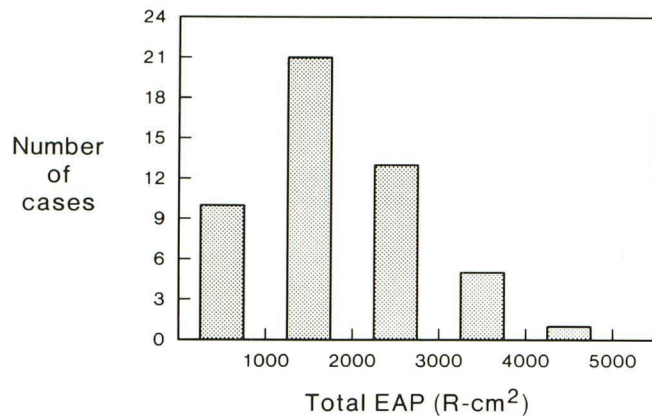


Fig. 1.—Total exposure-area product in 50 patients undergoing IV-DSA for atherosclerotic cerebrovascular disease.

imparted) provides a practical method with which to determine the somatic risk associated with diagnostic radiologic exposures.

The EAP is particularly useful in determining the total energy imparted to the patient in procedures in which the position of the X-ray beam and the field size vary, such as in fluoroscopic and cine procedures. Many studies using the EAP measurements for comparison purposes have been reported. The reader is referred to Leibovic and Fellows [12] and Bednarek et al. [13] for two recent examples.

This paper reports radiation exposures in representative samples of patients undergoing conventional screen-film angiography or IV-DSA for neurovascular disease.

Materials and Methods

Monitoring was performed on 149 patients: 76 underwent IV-DSA, 59 underwent conventional angiography, and 14 had both conventional angiography and IA-DSA. Of the 76 IV-DSA patients, 50 were examined for atherosclerotic disease of the carotid or vertebral vessels and 26 were examined as a postoperative evaluation after carotid endarterectomy. Of the 59 conventional angiography patients, 44 were examined for evaluation of atherosclerotic disease of the carotid or vertebral vessels and 15 for evaluation of intracranial mass lesions. A small number of patients who underwent examinations for miscellaneous indications (e.g., seizure disorder, arteriovenous malformation, or aneurysm) were not included in this study.

DSA was performed with a General Electric Digital Fluorocon 3000 system (Milwaukee, WI) with field sizes of 4, 6, and 9 in. (10.2, 15.2, and 22.9 cm), a 10-bit analog-to-digital converter, and a 512 × 512 matrix. All fluoroscopy and IV-DSA studies were performed without a grid. Exposure reduction by a factor of 0.5 is realized for fluoroscopy and DSA procedures carried out without a grid [14]. Elimination of the grid does not usually affect the contrast or resolution of the video image. As a result of the decreased exposure requirement, systems using kVp-variable or kVp-mA-variable automatic brightness control may operate at slightly lower kVp.

Standard projections consisted of right and left oblique views of the cervical vessels and a posteroanterior view of the intracranial circulation. As typically carried out, the examination used a 6-in. (15.2-cm) field of view at one frame/sec with a 4-sec injection-to-mask delay. Each projection typically consisted of a few test expo-

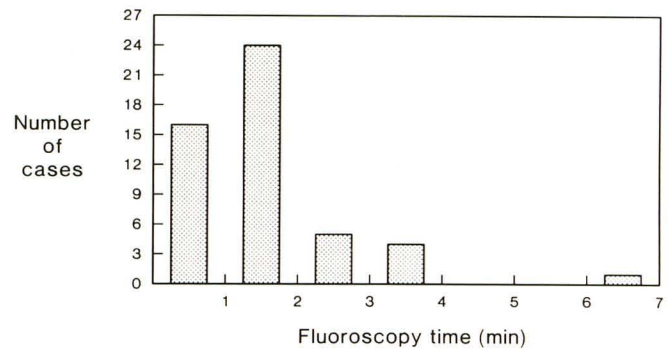


Fig. 2.—Fluoroscopy time in 50 patients undergoing IV-DSA for atherosclerotic cerebrovascular disease.

sure followed by 10–16 frames/projection. Occasionally, a 9-in. (22.9-cm) field was used for oblique views of the cervical carotid bifurcations and the carotid siphon together. For most IV-DSA examinations, contrast medium was injected through a 3½-in. (8.9-cm) IV catheter in an antecubital vein. Consequently, fluoroscopy was limited to patient positioning for each projection. If the antecubital route was unsuccessful, fluoroscopy was used for introduction of a transfemoral venous catheter.

Conventional angiography was carried out with the General Electric LU-A instrument, an Elema-Schonander Puck cut-film changer (Schaumburg, IL), a General Electric MSI 1250 IV X-ray generator, and a General Electric MX 125 X-ray tube. The screen-film combination used was Kodak X-Omatic regular screen with XL film. Angiography was performed with transfemoral catheterization and lateral and anteroposterior projections for each selective vessel catheterization. Typically, 10 films were used per projection. In some instances, additional injections were made or an oblique projection was added to obtain a better view of an area of interest.

EAP values for the fluoroscopic, digital, and radiographic portions of the examination as well as fluoroscopy time were obtained by using the Diamontor exposure monitor.

Results

The median EAP for the 50 patients who underwent IV-DSA examinations for atherosclerotic cerebrovascular disease was 1831 R cm² with a range of 366 to 4198 R cm² (Fig. 1). The median fluoroscopy time in these examinations was 1.3 min with a range of 0.6–6.3 min (Fig. 2). Fluoroscopy contributed 1.5–25% of the total EAP in these patients (median, 6%).

In the 26 patients who underwent IV-DSA as a postoperative evaluation after carotid endarterectomy, the median EAP was 742 R cm² (range, 86–2054 R cm²). The median fluoroscopy time was 0.8 min (range, 0.2–2.4 min), and fluoroscopy contributed 1.5–19.5% of the total EAP (median, 5%).

The 44 patients who underwent conventional screen-film angiography for atherosclerotic cerebrovascular disease had a median EAP of 3198 R cm² (range, 616–5665 R cm²) (Fig. 3). The median fluoroscopy time was 11.2 min (range, 2.0–23.9 min) (Fig. 4). Fluoroscopy contributed a median of 37% of the total radiation exposure (range, 8.8–76%).

The median EAP was 2141 R cm² (range, 808–5912 R

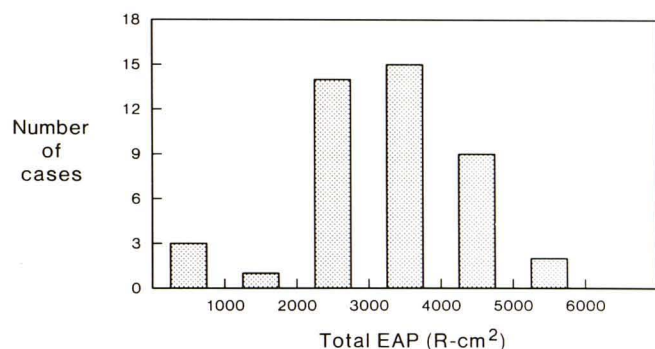


Fig. 3.—Total exposure-area product in 44 patients undergoing conventional angiography for atherosclerotic cerebrovascular disease.

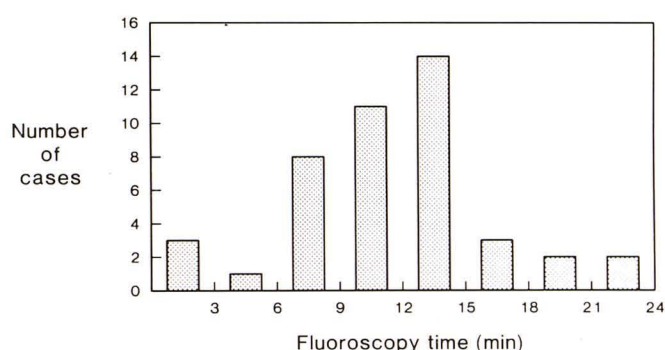


Fig. 4.—Fluoroscopy time in 44 patients undergoing conventional angiography for atherosclerotic cerebrovascular disease.

cm²) in the 15 patients who underwent conventional angiography for evaluation of an intracranial mass lesion. The median fluoroscopy time was 6.1 min (range, 1.5–20.6 min). Fluoroscopy contributed a median of 32% of the total exposure (range, 8–73%).

Fourteen patients underwent combined conventional angiography and IA-DSA because abnormal vascular anatomy made selective arterial catheterization extremely difficult or hazardous. The median EAP was 5716 R cm² (range, 1425–10,433 R cm²). The median fluoroscopy time was 17.5 min (range, 3.3–33.4), and fluoroscopy accounted for a median of 27% (range, 8.5–46.5%) of the total EAP.

Discussion

A wide range of exposure values was observed in both the IV-DSA and conventional angiographic examinations. In the IV-DSA studies, repeat injections were sometimes necessary because of patient motion or vessel overlap. The number of frames taken per projection also varied according to the patient's cardiac output. Although the amount of fluoroscopy time usually was limited in IV-DSA, in some cases difficulties in proper positioning of the patient, the use of a transfemoral venous approach, or increased patient thickness resulted in an increased fluoroscopic exposure.

In conventional angiography, the radiographic exposure varied with the number of vessels catheterized and the number of radiographic series taken. The wide range in the amount of fluoroscopic exposure was a result of differences in difficulty of selective vessel catheterization, in the abilities of the persons performing the catheterization, and in the thickness of the patient. No correlation was observed between the patient's age and the amount of fluoroscopy time.

In patients who were examined for atherosclerotic cerebrovascular disease, the median EAP in the conventional angiography group was 1.7 times greater than that of the IV-DSA group. This difference in exposure between the two groups was primarily a result of increased use of fluoroscopy in the conventional angiography group. The median fluoroscopy time and fluoroscopic EAP in the conventional group was 11.2 min and 1100 R cm², respectively, compared with 1.3 min and 108 R cm² in the IV-DSA group. The median contribution of fluoroscopy to the total exposure was 37% in the conventional group and 6% in the IV-DSA group. In contrast, Pavliceck et al. [7] reported contributions of 70% and 36%, respectively. The actual imaging portion of the two examination methods showed a much smaller difference—median digital EAP of 1641 R cm² (range, 314–3950 R cm²) and a median conventional EAP of 1926 R cm² (range, 373–4192 R cm²). The number of digital frames taken (median, 46; range, 36–75) was similar to the number of films taken in the conventional screen-film group (median, 50; range, 10–90).

The median EAP in the IV-DSA examinations of postoperative carotid endarterectomy patients was less than half that of patients who underwent IV-DSA for evaluation of atherosclerotic disease. Because these examinations are directed at demonstrating postoperative vessel patency, fewer projections and digital frames are necessary. The contributions of fluoroscopy to total exposure were approximately the same in the two groups.

The 15 patients who underwent conventional angiography for evaluation of an intracranial mass lesion had a lower total EAP than did those examined for atherosclerotic disease. The reason for this difference was that the lesion was usually unilateral and typically, a one- or two-vessel catheterization with two to four radiographic series was performed, compared with the two- to four-vessel catheterization typical in evaluation of an atherosclerotic process.

The exposure was significantly higher in the 14 patients who required a combined conventional and IA-DSA examination than it was in the other groups studied. The fluoroscopy times were increased (median, 17.5 min), attesting to the difficulty of selective catheterization in these patients. The use of IA-DSA allowed the examination to be completed with less risk of angiographic complication because of the less-selective catheterization necessary with IA-DSA. Moreover, the amount of fluoroscopy time, and thus patient radiation exposure, was less than what it would have been had a difficult selective catheterization been used.

The introduction of digital subtraction techniques has added a new dimension to cerebral angiography. Although the use of IV-DSA as a definitive diagnostic examination in symptomatic cerebrovascular disease is doubtful [15], IV-DSA still

plays an important role as a screening examination for cerebrovascular disease because it offers a noninvasive procedure that can be performed rapidly on an outpatient basis at less cost and with less radiation exposure to the patient.

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