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Flexible lateral isocenter: A novel mechanical functionality contributing to dose reduction in neurointerventional procedures

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Abstract
Aim of the study: A new functionality that enables vertical mobility of the lateral arm of a biplane angiographic machine is referred to as the flexible lateral isocenter. The aim of this study was to analyze the impact of the flexible lateral isocenter on the air-kerma rate under experimental conditions.

Material and methods: An anthropomorphic head-and-chest phantom with anteroposterior (AP) diameter of the chest varying from 22 cm to 30 cm simulated human bodies of different body constitutions. The angulation of the AP arm in the sagittal plane varied from 35 degrees to 55 degrees for each AP diameter. The air-kerma rate (mGy/min) values were read from the system dose display in two settings for each angle: flexible lateral isocenter and fixed lateral isocenter.

Results: The air-kerma rate was significantly lower for all AP diameters of the chest of the phantom when the flexible lateral isocenter was used: (a) For 22 cm, the p value was 0.028; (b) For 25 cm, the p value was 0.0169; (c) For 28 cm, the p value was 0.01005 and (d) For 30 cm, the p value was 0.01703.

Conclusion: Our results show that the flexible lateral isocenter contributes significantly to the reduction of the air-kerma rate, and thus to a safer environment in terms of dose lowering both for patients and staff.

Keywords
Lateral isocenter, biplane angiographic machine, dose saving

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the factors on which the dose is dependent is the distance between the detector panel and X-ray tube.

**Material and methods**

The biplane machine used in this study was the Toshiba Infinix-i/BP (Toshiba Medical Systems, Shimoishigami, Otawara-shi, Tochigi, Japan). The technical characteristics of the fluoroscopy used for the measurements were detector input dose of 0.45 mGy/s for a reference field of view (FOV) of 20 × 20 cm, which was used for all measurements. The X-ray factors were voltage, 80 kV; range of current, 50–200 mA; and filtration, 0.3 mm copper. Current (mA) and time (ms) are not constant in fluoroscopy as they vary according to the automatic brightness control (ABC) response.

FLIC enables adjustment of the lateral arm in the vertical direction.

The air-kerma rate (mGy/min) values were read from the system dose display.

The head of an anthropomorphic head-and-chest phantom with AP diameters of the chest measuring 22 cm, 25 cm, 28 cm and 30 cm for each dose measurement was used as a target. The AP diameter of the thorax was extended by adding 1 or 2 cm thick Plexiglas plates. The distance between the detector plate of the AP arm and the thorax was always 2 cm. The caudo-cranial angulation of the AP arm varied from 35 degrees to 55 degrees, with a 5-degree increment between measurements.

To achieve the needed caudo-cranial angulation, to keep lateral projection of the target, and to avoid collision between the AP arm and the chest of the phantom, the distance between the X-ray tube and detector plate increased for each angulation when the non-flexible isocenter (non-FLIC) was used (Figure 1). When the FLIC was used, the same aim was achieved by vertical adjustment of the lateral arm and a marginal increase of the distance between X-ray tube and detector plate (Figure 2). For both FLIC and non-FLIC setups the exposed anatomical area and volume (head of the head-and-chest phantom) were the same for each measurement. This ensured the air-kerma values for both setups were comparable and dependent only on the distance between the X-ray tube and detector plate.

The Excel T test was used for statistical analysis of the results. For the difference between air-kerma values, a p value <0.05 was considered significant.

**Results**

**(a) Thorax AP diameter: 22 cm**

When the non-FLIC was used, the distance between the X-ray tube and detector plate increased from 97 cm to 118 cm as the angulation in caudo-cranial direction increased from 35 degrees to 55 degrees. Thus the lateral projection was not lost regardless of angulation, and the detector plate did not collide with the thorax of the phantom. The increase of distance caused an increase of dose from 16.3 mGy/min to 39.7 mGy/min (Figure 3). When the FLIC was used, the lowering of the table was compensated for by vertical adjustment of the lateral arm and a marginal increase of distance between the X-ray tube and detector plate: from

![Figure 1](Interventional Neuroradiology 23(6))
95 cm for 35 degrees to 105 cm for 55 degrees. This increase in distance caused an increase in dose from 14 mGy/min to 19.2 mGy/min (Figure 3).

(b) Thorax AP diameter: 25 cm

When the FLIC was used, the increase of angulation from 35 degrees to 55 degrees was compensated for by vertical adjustment of the lateral arm and an increase in the distance between the X-ray tube and detector plate from 95 cm to 108 cm, which was followed by a dose increase from 15.9 mGy/min to 29.8 mGy/min (Figure 4). For the same angulations, the distance between the X-ray tube and detector plate increased from 101 cm to 123 cm when the non-FLIC was used. This increase of distance caused an increase of the dose from 17.9 mGy/min to 40.6 mGy/min (Figure 4).
(c) **Thorax AP diameter: 28 cm and 30 cm**

For these two AP diameters, the angulation of 55 degrees could not be reached when the non-FLIC was used. For an AP thorax diameter of 28 cm, the distance between the X-ray tube and detector plate increased from 103 cm to 125 cm and an angulation of 54 degrees was reached. This was followed by a dose increase from 18.7 mGy/min to 44.2 mGy/min (Figure 5). Similarly, for the AP thorax diameter of 30 cm, the distance between the X-ray tube and detector plate increased from 106 cm to 124 cm and an angulation of 50 degrees was reached. This increase in distance led to a dose increase from 19.9 mGy/min to 40.2 mGy/min (Figure 6). The angulation of 55 degrees was reached for both AP thorax diameters when the FLIC was used. For these two diameters, the distance between the X-ray tube and detector plate increased from 95 cm to 113 cm and from 96 cm to 116 cm, respectively. This was followed by a dose increase from 15.6 mGy/min to 34.9 mGy/min and 16.8 mGy/min to 41.5 mGy/min, respectively (Figures 5 and 6).

The Excel $T$ Test showed that the dose when the FLIC was used was significantly lower ($0.001 < p$ value $< 0.05$) than the dose when the non-FLIC was used for each thorax diameter (Figures 3–6):

(e) For 22 cm, the $p$ value was 0.028;

![Figure 4. Air-kerma rate is significantly lower for thorax anteroposterior diameter of 25 cm when the flexible lateral isocenter was used, $p$ value = 0.0169.](image1)

![Figure 5. Air-kerma rate is significantly lower for thorax anteroposterior diameter of 28 cm when the flexible lateral isocenter was used, $p$ value = 0.01005. When the non-flexible lateral isocenter was used, the maximum achieved angulation was 54 degrees.](image2)
(f) For 25 cm, the \( p \) value was 0.0169;
(g) For 28 cm, the \( p \) value was 0.01005 and
(h) For 30 cm, the \( p \) value was 0.01703.

**Discussion**

Since the beginning of the era of endovascular treatment of cerebral aneurysms, arteriovenous malformations and fistulas, optimal visualization of these targets has been the main prerequisite for a successful treatment and the object of numerous studies.\(^1\)\(^-\)\(^3\) The visualization of these vascular structures has evolved from monoplane and biplane fluoroscopy to three-dimensional (3D) rotational angiography.\(^4\)\(^,\)\(^5\) Moreover, the evolution of computerized tomographic angiography as well as magnetic resonance tomographic angiography enabled almost noninvasive visualization of the angioarchitecture of cerebral aneurysms, arteriovenous malformations and fistulas without exposing patients to the risks related to trans-catheter angiography.\(^6\)\(^-\)\(^8\) The preoperative, 3D visualization of cerebral vascular structures is the first and very important step in the planning of the treatment of these conditions. Since the consequences of complications that sometimes occur during endovascular intervention are often disastrous, an adequate visualization of the vascular target during treatment is essential for the appropriate choice of devices and techniques. The biplane systems have become an obligatory part of the equipment of an angiographic theater intended for neurointerventional procedures. The superiority of a biplane system compared to a monoplane system cannot be scientifically proven based on existing data in the scientific literature, but this system can definitely improve operators confidence, which should provide a better treatment in terms of reduced risk of complications and better radiological and clinical result of the intervention.\(^9\)

All state-of-the-art biplane machines possess two arms intended for visualization of vascular structures in two planes, which are, in the neutral position, perpendicular to each other. During the intervention, the angulation of these arms is changed in order to obtain the optimal visualization of a vascular target. Both arms are constructed so that the angle between the axis of the X-rays and the detector plate is 90 degrees, and this axis always hits the intersection of the diagonals of the detector plate. This intersection, which is the geometric center of the detector plate, is referred to as the isocenter. The distance between the X-ray source and the detector plate is flexible and referred to as the source-to-image distance (SID). Below the angulations, the only possible mobility of the lateral isocenter of all state-of-the-art biplane machines, except the Toshiba Infinix-i/BP, is the mobility in the horizontal direction. The FLIC, which enables additional mobility in the vertical direction of the lateral isocenter, is integrated in all commercially available Infinix-i/BP machines.

The amplitude of the angulation of both arms is very high regardless of the model of the bi-plane system because of the specific demands for optimal visualization of cerebral vascular structures. A factor that limits the full capacity of the angulation is the table that carries the body of the patient connected by tubes and cables with anesthetic and neurosurgical systems for monitoring and maintenance of vital functions. The amplitude of vertical movement of the FLIC is 14 cm, which corresponds to approximately 75% of a mean AP diameter of the head of an adult human.\(^10\) This means that the FLIC markedly expands the capacity of angulation of both arms and in this way contributes

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**Figure 6.** Air-kerma rate is significantly lower for thorax anteroposterior diameter of 30 cm when the flexible lateral isocenter was used, \( p \) value = 0.01703. When the non-flexible lateral isocenter was used, the maximum achieved angulation was 50 degrees.
to easier achievement of the optimal visualization of vascular targets with challenging angioarchitecture. Our experimental work has shown that the FLIC enables such visualization with a marginal increase of SID, at least in the AP projection.

Since the beginning of the era of neurointervention, X-ray equipment has evolved tremendously in terms of improved image quality and decreased fluoroscopic and angiographic doses. This development is based on technical improvements of X-ray generators, hardware and software for acquisition of data and generation of images, as well as on the improvements in radiation-protection systems integrated into the biplane machines.11–15 The biggest challenge to the improvement of dose-saving systems is that the image quality must be kept on an optimal level regardless of the dose reduction.16 The most frequent and the easiest way of reducing the dose is optimization of existing parameters of fluoroscopy and angiography.16–19 Spot fluoroscopy, a qualitatively new type of asymmetric collimation, represents a breakthrough in the technology of dose-reduction systems.20

The FLIC is also a qualitatively new technical solution that originally was aimed at improvement of the amplitude of angulation of both arms. Thanks to the FLIC, even extreme angulations can be achieved without or with marginal extension of the SID. Thus the FLIC also prevents the dose increase caused by the SID increase, which is inevitable if a non-FLIC system is used for achieving these angulations. This was clearly shown by our experiment.

This experimental study has certain limitations. The effect of the FLIC on the amplitude of angulation has been described only briefly and not elaborated on in detail since we assumed that this issue is comprehensible “per se.” The measurements of the dose were carried out in only the sagittal plane because measurements in several planes of both arms would involve a much more complex study design, with the same or very similar results. Finally, the only parameter we measured in this experiment was the air kerma rate.

Conclusion

The FLIC is a novel, original functionality intended for better exploitation of existing technical capabilities of the arms of a biplane angiographic machine. Our experimental work, in spite of certain methodological limitations, clearly shows that the FLIC also contributes to a significant dose reduction, at least in the AP plane. In other words, the FLIC is a functionality that effectively couples two independent but equally important functionalities of each angiographic machine.

Declaration of conflicting interests

The authors declared the following potential conflicts of interest with respect to the research, authorship, and/or publication of this article: The Unit for Neurointervention in our department is Toshiba’s reference site. AP is a Toshiba employee, an engineer, and International Clinical Development Manager.

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