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Adrenal Vein Sampling: Radiation Dose Reduction on New Angiography Platform

Abstract

Objectives: Primary aldosteronism is one of the most common causes of secondary hypertension. Distinguishing unilateral from bilateral disease is essential as those with unilateral adrenal disease will benefit from adrenalectomy. This is best achieved by adrenal vein sampling (AVS) which may be a difficult procedure with significant radiation to both patient and operator. This study aims to measure the radiation dose during AVS before and after the installation of a new angiography platform. **Materials and Methods:** The dose area product (DAP), air kerma, and fluoroscopy time were collected retrospectively together with demographic data for the first ten patients who underwent AVS between April and September 2018 following the installation of the Philips Azurion 7 M20 interventional platform. These results were compared with those from ten patients who underwent AVS before the installation of the new machine using the Philips Allura Xper FD20 platform. Mann–Whitney test was used to compare DAP, air kerma, and fluoroscopy time. $P < 0.05$ was considered statistically significant. **Results:** Successful bilateral adrenal vein catheterization was achieved in all cases in both groups. There was no significant difference in fluoroscopy time: 5.5 (3.3–10.8) min (new) versus 5.3 (4.5–8.4) min (old) ($P = 0.9502$). The DAP and air kerma were both significantly lower on the new machine: 11.3 (5.2–26.7) Gy.cm^2 versus 45.5 (17.2–56.5) Gy.cm^2 ($P = 0.0089$) and 201.5 (88.1–464.0) mGy versus 682.5 (300.5–998.5) mGy ($P = 0.0115$), respectively. **Conclusion:** The installation of the Philips Azurion 7 M20 interventional platform has allowed a significant reduction in radiation dose during AVS.

Keywords: *Adrenal glands, dosimetry, hyperaldosteronism, interventional, radiation dosage, radiology, vascular surgical procedures*

Ali Alsafi, Florian Wernig[1], Jeannie Todd[1], Tricia Tan[1], F. Fausto Palazzo[2], Karim Meeran[1], James E. Jackson

Departments of Imaging and [1]Endocrinology, Imperial College Healthcare NHS Trust, Hammersmith Hospital, [2]Department of Endocrine and Thyroid Surgery, Imperial College London, Hammersmith Hospital, London, England

Introduction

Primary aldosteronism is now recognized as being a common cause of hypertension and is associated with a higher risk of serious cardiovascular complications than in those patients with blood pressure-matched essential disease.[1-3] Once autonomous secretion of aldosterone independent of regulators[4,5] has been confirmed biochemically, adrenal venous sampling (AVS) is the gold standard modality used to differentiate those individuals with unilateral secretion due to an adrenal adenoma (Conn's syndrome) from those with bilateral adrenal hyperplasia, as the former is likely to benefit considerably from unilateral adrenalectomy.[6]

AVS is a technically challenging procedure with a significant learning curve and may result in significant radiation exposure to both patient and operator.[7] The published median dose area product (DAP) for AVS ranges between 32.5 Gy.cm^2 and 72.2 Gy.cm^2,[8-11] although doses as low as 15.7 Gy.cm^2 have been reported using the intraprocedural measurement of cortisol.[11]

New dose constraints

The Ionising Radiation (Medical Exposure) Regulations 2017 (IR (ME) R17) came into force on 6 February 2018 in the United Kingdom, replacing and revoking IR (ME) R2000. One of the changes in these new regulations is a reduction in the maximum yearly radiation dose to the lens of the eye of the operator from 150 mSv to 20 mSv. This has resulted in an even greater awareness of radiation exposure resulting in a nationwide move to upgrade interventional radiology rooms with machines that reduce radiation exposure to both operator and patient while maintaining image quality. In line with this policy, we

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Address for correspondence:
Dr. Ali Alsafi, Department of Imaging, Imperial College Healthcare NHS Trust, Hammersmith Hospital, London, England. E-mail: ali.alsafi03@alumni.imperial.ac.uk

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have replaced an Allura Xper FD20 (Philips Healthcare, Best, The Netherlands) with a Philips Azurion 7 M20 (Philips Healthcare, Best, The Netherlands). The Azurion 7 M20 incorporates the ClarityIQ system by Philips with real-time image processing for noise reduction, edge enhancement, and motion correction with additional filtering and optimized protocols lowering radiation dose while maintaining a diagnostic image quality. The larger screen also allows for improved visualization at lower radiation doses.[12,13]

The aim of this article is to assess and compare radiation dose (DAP, air kerma, and fluoroscopy time) during adrenal venous sampling at a tertiary referral center before and after the installation of a new angiography machine.

Materials and Methods

The first ten patients to undergo adrenal venous sampling between April and September 2018 following the installation of the Philips Azurion angiography machine were identified from the picture archiving and communication system. Demographic data and procedural details, including the success of adrenal vein catheterization, fluoroscopy time, DAP, and air kerma were collected retrospectively. These results were compared with those of the last ten patients to undergo AVS on the Philips Allura machine. To exclude variations in patient size as being the cause of differences in radiation dose between the two groups, measurements of abdominal circumference and anteroposterior (AP) abdominal diameter were made at the level of the adrenal glands on the most recent computed tomography (CT) or magnetic resonance imaging performed before AVS.

Adrenal vein sampling technique

As the technique of adrenal vein sampling (AVS) varies somewhat between centers,[14,15] we will briefly describe our own protocol. All procedures are performed as day cases. Sampling is performed through a right femoral venous puncture with a 4Fr Glidecath® hydrophilic coated Cobra catheter (Terumo, Tokyo, Japan) within which we punch two holes 2 mm from its tip in the sagittal plane of the lumen as originally described by Doppman and Gill.[15] A fluoroscopy rate of 15 frames/s is used, and digital subtraction angiography images are acquired at 2 frames/s.

The right adrenal vein is always catheterized first, and venography is performed to confirm normal adrenal vein opacification. If appropriately positioned, a 5–10 ml sample of blood is obtained by slow aspiration after discarding the first 2–3 ml of catheter dead space. If there is any concern that the catheter tip was not ideal during aspiration, then an additional sample is obtained after again confirming an appropriate catheter position. Each sample bottle is numbered in turn, and these numbers are transcribed onto a diagram of normal venous anatomy [Figure 1] used by our department for all venous sampling procedures to document the vessel from which the sample has been aspirated. The common trunk of the left adrenal and inferior phrenic veins is then catheterized. In approximately 90% of cases, this can be achieved with the same catheter. In the remainder, a 5 French Sidewinder II catheter (Cardinal Health, Santa Clara, CA, USA) is used. Venography is performed to confirm a satisfactory catheter position, and a venous sampling is obtained in the same way as previously described. We neither use cone-beam CT (CBCT) nor image fusion to aid cannulation. A single sample is then obtained from the low inferior vena cava (IVC). All sampling is done without Synacthen stimulation. All samples are taken to the endocrine laboratory by the operator immediately after the procedure with a copy of the venous map.

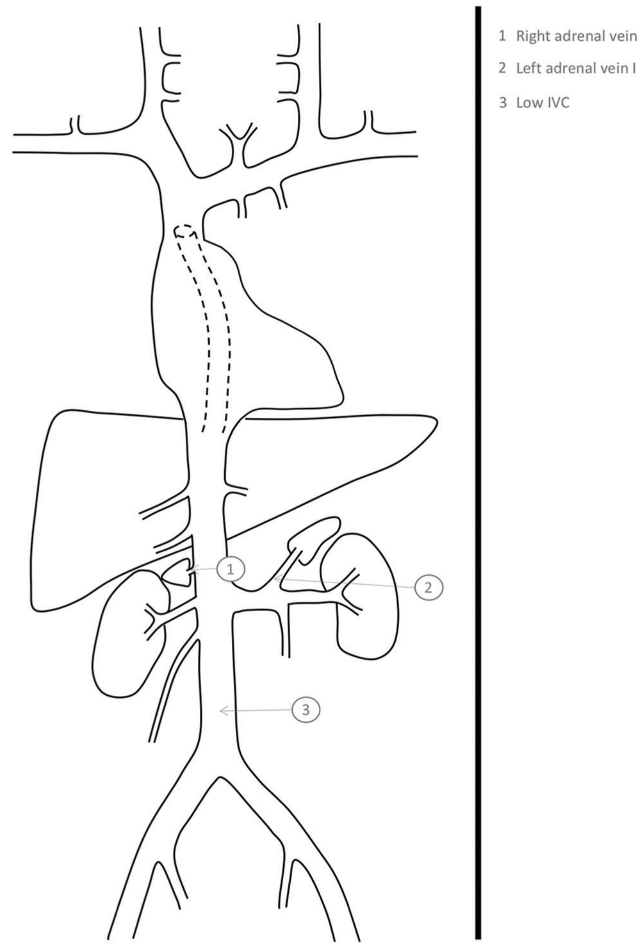

Figure 1: Venous sampling map used by the authors for all venous sampling procedures on which sampled vessels are indicated in the order they are obtained with a legend indicating the vessels sampled on the right-hand side

Successful catheterization

Serum cortisol and aldosterone concentrations are measured in all samples. Successful adrenal vein catheterization is considered to have been achieved when the adrenal vein cortisol concentration is at least twice that of the low IVC.[5]

Statistical analysis

GraphPad Prism 6.0 for Mac OS (GraphPad Software Inc., San Diego, CA, USA) was used for statistical analysis. The Mann–Whitney test was used to compare DAP, air kerma, and fluoroscopy time. Unpaired student *t*-test was used to compare the abdominal circumference and AP diameters. All results are expressed as mean or median and interquartile range. $P < 0.05$ were considered statistically significant.

Results

The Philips Allura (M: F = 5:5) and Philips Azurion groups (M: F = 3:7) had a median age of 49.8 years (29.7–63.0) and 47.3 (26.0–66.2), respectively. All patients were referred with a confirmed diagnosis of primary aldosteronism, one of whom had recurrence 10 years following previous left adrenalectomy at another center without prior venous sampling. AVS was performed to confirm the absence of residual functioning adrenal tissue on that side.

The median DAP on the Azurion of 11.3 (5.2–26.7) Gy.cm^2 was significantly lower than the 45.5 (17.2–56.5) Gy.cm^2 on the Philips Allura. ($P = 0.0089$, Mann–Whitn1 [Figure 2]. The median air kerma on the Azurion was 201.5 (88.1–464.0) mGy, which was significantly lower than that on the Philips Allura, 682.5 (300.5–998.5) mGy ($P = 0.0115$, Mann–Whitney test) [Figure 3].

There was no significant difference in fluoroscopy time between the Allura and Azurion groups with median fluoroscopy times of 5.5 (3.3–10.8) min and 5.3 (4.5–8.4) min, respectively. ($P = 0.9502$, Mann–Whitney test) [Figure 4]. There was no significant difference between the two patient groups in the mean abdominal circumference or abdominal AP diameter, excluding patient size variation as a potential confounder [Table 1].

Successful bilateral adrenal venous catheterization confirmed by an appropriate elevation of cortisol concentration with respect to the IVC was achieved in all but one patient. This "failed" left adrenal venous catheterization occurred in the individual referred with recurrent hyperaldosteronism 10 years following previous left adrenalectomy performed at another center. AVS was performed to exclude functioning adrenal tissue on the left side, and this was confirmed by the baseline cortisol and aldosterone concentrations in the left adrenal vein sample.

Discussion

Primary aldosteronism is a much more common cause of hypertension than previously recognized, and this has resulted in a significant increase in the number of patients referred for adrenal venous sampling.[3] Bilateral adrenal vein catheterization may be difficult, although success rates are high in tertiary referral centers when the procedures are performed by single operators.[7,16] This is true of our own institution, where a single operator has achieved a 97% successful bilateral sampling rate over the past 8 years using the technique described in this article.

Less-experienced operators, however, may fail to catheterize the right adrenal vein in up to 50% of cases,

Table 1: Abdominal circumference and anteroposterior diameter on cross-sectional imaging for the Allura and Azurion groups

	Abdominal circumference (cm)	Abdominal AP diameter (cm)
Azurion group (*n*=9)	101.1 (82.5-112.0)	26 (20-29.5)
Allura group (*n*=10)	99.3 (89.3-110.8)	25.5 (23-29.5)
P	0.8084	0.8257

There is no significant difference in abdominal size between the Allura and Azurion groups. Results expressed as the mean and interquartile range. Unpaired student *t*-test used. AP: Anteroposterior

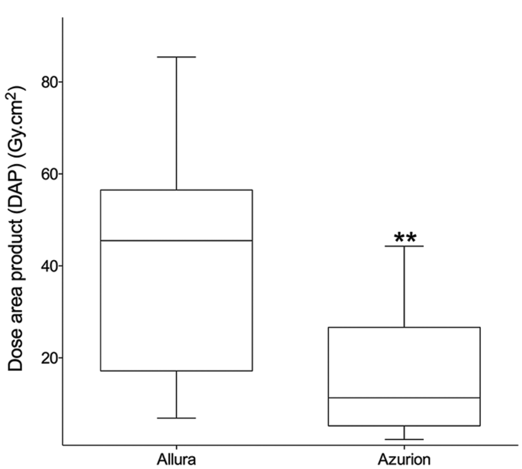

Figure 2: Dose area product in Gy.cm2 during adrenal vein sampling before and after installation of the Philips Azurion angiography machine. ***P* **< 0.01, Mann–Whitney test. Line = median, box = interquartile range, whiskers = 95% confidence interval

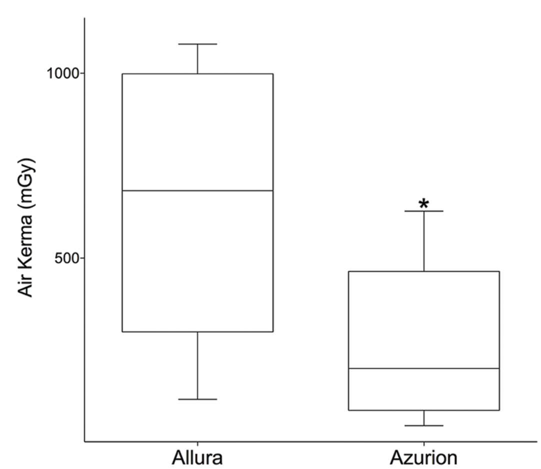

Figure 3: Air kerma (mGy) during adrenal vein sampling before and after installation of the Philips Azurion angiography machine. *P < 0.05, Mann–Whitney test. Line = median, box = interquartile range, whiskers = 95% confidence interval

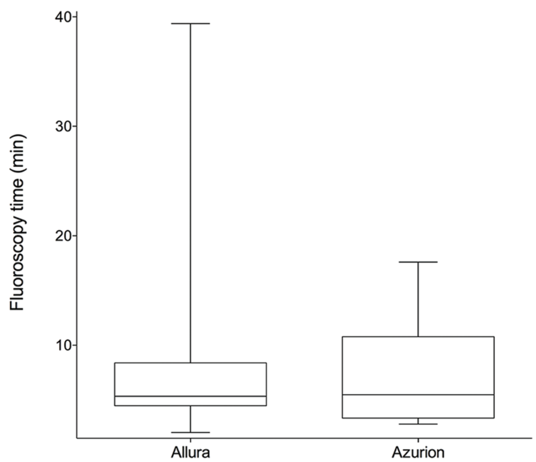

Figure 4: Fluoroscopy time (min) before and after installation of the Philips Azurion angiography machine. Line = median, box = interquartile range, whiskers = 95% confidence interval

and several techniques have been tried in an attempt to improve these results including intraprocedural CBCT, which has reported successful catheterization rates of 89–95%[16-19] and intraprocedural cortisol assays with reported success rates of 81%–93%.[20,21] The first of these is associated with an increased radiation dose, and both are costlier than the conventional catheterization technique described here. The median DAP during AVS in the study was 11.3 $Gy.cm^2$, which is lower than previously published reports ranging between 32.5 $Gy.cm^2$ and 72.2 $Gy.cm^2$[8-11] including on some new generation angiography machines. Some of the differences may be, as some groups use CBCT to improve the success rate at the expense of an increased dose. Differences in operator experience are also likely to significantly affect radiation exposure during AVS.

Intraprocedural image fusion of prior CT data with live fluoroscopic images has been shown to aid right adrenal vein catheterization and to reduce both fluoroscopy time and radiation exposure.[10] The authors of this article have shown a relative reduction in their radiation use, but the technique is still associated with a significant radiation dose and a prolonged procedure time. It may be a useful technique to help inexperienced operators improve right adrenal vein catheterization during initial procedures. Regardless of the technique that is used, it is important that every effort is made to reduce radiation dose to both patient and operator during adrenal vein sampling, and our results demonstrate that a significant reduction has been achieved in our own practice since the installation of the Philips Azurion 7 M20 angiography platform while maintaining a 100% adrenal vein catheterization rate.

We chose AVS in order to compare radiation dose before and after installation of the new machine as the procedure has a well-defined endpoint with an objective measure of success, therefore reducing subjective confounders. Most other interventional radiology procedures have many other variables making a fair comparison of the two angiography platforms difficult. It is likely, however, that this radiation dose reduction translates to other X-ray-guided interventions. The Azurion 7 M20 includes hardware and software upgrades which allow real-time pixel shifting to correct for motion, as well as noise reduction by temporal and spacial pixel averaging.[12,13] These changes, together with optimized protocols and a larger viewing screen, counterbalance the reduction in radiation dose and allow for maintained diagnostic image quality.[12,22]

Some of the limitations of this article include the small sample size, but this is mitigated by controlling for confounders including gender and weight as well as all procedures being performed by a single operator. No real-time dosimetry measurements were taken, instead, the DAP and air kerma were obtained from the Allura and Azurion's internal dose reporting systems. As the measurement methods are similar, however, this allowed for a fair comparison. The retrospective nature of this study makes it difficult to account for all confounders; however, the study reflects clinical practice.

The installation of the Philips Azurion 7 M20 angiography machine has resulted in a fourfold reduction in DAP and a threefold reduction in air kerma during adrenal venous sampling. This reduction in radiation dose had no effect on the success rate of AVS and no effect on fluoroscopy time. This reduction in radiation dose to the patient will also significantly reduce radiation dose to the operator, which is particularly important in view of the recently introduced IRR17 radiation protection rules.

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Conflicts of interest

The authors have no conflict of interest.

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