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INTERVENTIONAL RADIOLOGY

ORIGINAL ARTICLE

Radiological characteristics and diagnostic impact of duplicated right adrenal veins on adrenal venous sampling in primary aldosteronism

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PURPOSE
We aimed to analyze the prevalence and radiological characteristics of duplicated right adrenal veins (DRAVs) and evaluate the diagnostic impact of adrenal venous sampling (AVS) in primary aldosteronism.

METHODS
DRAVs were retrospectively identified among patients who underwent segmental AVS between April 2017 and March 2020. DRAVs were defined as main or accessory according to the drainage area. The diameter, position, hormone levels, and treatment plan based on AVS were compared between main and accessory RAVs, using the Wilcoxon rank-sum test.

RESULTS
Fourteen of 432 patients (3.2%) were diagnosed with DRAVs. On venography, the mean diameters of the main and accessory side were 3±0.63 mm and 2.1±0.41 mm, respectively, and were significantly different ($p < 0.001$). The mean relative position in craniocaudal direction of main and accessory veins from the adrenal caudal edge on computed tomography was 65.5%±16.0%, and 48.1%±16.8%, respectively, which was significantly different ($p = 0.007$). The left–right positions and hormone levels were not significantly different. Based on conventional AVS, the treatment plan between DRAVs was not changed in six of eight patients, but changed from surgery to medication in two patients with right aldosterone-producing adenoma (APA)/microadenoma based on segmental AVS findings.

CONCLUSION
DRAVs, in which the main RAV was thicker and more cranially located than the accessory RAV were rare. Depending on blood sampled from either of DRAVs, the diagnosis made through conventional AVS might change treatment approach from surgery to medication, especially with right APA. Hence, their identification is important to make an accurate subtyping by AVS.

Primary aldosteronism (PA) is the most common cause of secondary hypertension and accounts for 3%–10% of hypertension cases (1, 2). The frequency of complications is higher in PA than in essential hypertension (3, 4). Aldosterone-producing adenoma (APA) and bilateral idiopathic hyperaldosteronism (IHA) are the two most common subtypes of PA, and adrenal venous sampling (AVS) is the standard method for subtyping (1, 2, 5). In some facilities, segmental adrenal venous sampling (sAVS) is performed using a super selective catheterization technique on the adrenal tributaries, in addition to central adrenal venous sampling using conventional AVS (cAVS) (6–11).

The success rate of cAVS varied greatly from 31%–98% (12–14), mainly because of the difficulty of sampling blood from the right adrenal vein (RAV) due to its small size and anatomical variation. Analyzing RAV in the preprocedural computed tomography (CT) is important for technical success (13).

Descriptions of adrenal venous variations, including duplication, have been reported in cadaver studies or as surgical observations (15–19). However, discussion on radiological findings and significance of AVS-based diagnosis was limited to only a small comment in a few reports or one case report with CT detection during right inferior phrenic arteriography with AVS; hence, not much is known (20–22). The study aim was to analyze the prevalence and radiological characteristics of duplicated RAVs (DRAVs) and evaluate the diagnostic effect on AVS in patients with PA.

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Methods

The protocol for this retrospective study was approved by the relevant institutional review boards, and written informed consent was waived because of the retrospective design (IRB approval number: 30-94-2). The data of patients who were diagnosed with PA according to the guidelines (1, 2) and underwent sAVS between April 2017 and March 2020 were included.

CT examination

All patients underwent non-contrast and contrast-enhanced dynamic CT examinations for evaluation of adrenal tumors and adrenal veins prior to sAVS. We used a 64-row multidetector CT scanner (Aquilion 64, Toshiba). The helical CT data were reconstructed in the axial plane as 0.5 mm sections at 0.3 mm intervals before storage and then transferred to a workstation (Ziostation2, Ziosoft) where the reconstructed axial helical sections were reformatted in the axial, coronal, and sagittal planes at 1.0 mm intervals with a 1.0 mm slice thickness. Two-phase dynamic scans were performed. A 100 mL volume of nonionic contrast material containing 350 mg/mL Iohexol (Omnipaque 350, Daiichi Pharmaceutical) was injected into a medial cubital vein for 25 seconds. The bolus-tracking method was used for the late arterial phase, and the start time was determined manually when the left renal vein was contrasted. The patients were instructed to breathe in and hold while being scanned and were scanned again for the delayed phase 120 seconds after starting administration.

Main points

- Based on venography during adrenal venous sampling (AVS), duplicated right adrenal veins (DRAVs) were observed at a frequency of 3.4% among patients with primary aldosteronism.
- DRAVs were defined as main and accessory based on the extent of the drainage area; main DRAVs were thicker and more cranially located.
- Depending on blood sampled from either of DRAVs, the diagnosis made through conventional AVS remained same in many patients, but might change treatment from surgery to medication in some cases, especially with right aldosterone-producing adenoma. Hence, identification of DRAVs is important to make an accurate subtyping by AVS.

sAVS procedure and DRAV determination

The procedure was performed by interventional radiologists with >30 years of experience and attending radiologists, with endocrinologists in attendance. A 5 F sheath was inserted in the right femoral vein. A 5 F diagnostic catheter (MK adrenal type, Hanaco Medical Co., Ltd.), 2–2.7 F split-tip microcatheter (Gold Crest Co., Ltd.), and a 0.035-inch guidewire (Radifocus, Terumo) or 0.018-inch guidewire (Aqua V3, Cordis) were used. Intravenous bolus injection of 200 μg synthetic adrenocorticotropic hormone (cosyntropin) via the peripheral vein was followed by a 50 μg/h drip infusion 30 minutes later (23). Blood was collected from the left and right adrenal central veins (ACVs) and the right external iliac vein before and 15–90 min after cosyntropin loading; blood was also sampled from the bilateral adrenal tributary veins and left common trunk at the confluence of the left ACV and inferior phrenic vein after cosyntropin loading. sAVS was used to diagnose APA, CT-undetectable aldosterone-producing microadenoma (APmicroA), cortisol-producing adenoma (CPA), and IHA by recognizing the heterogeneity of hormone production within the adrenal glands, as previously reported (9).

Although DRAVs were identified on contrast CT images in some cases, in practice, periadrenal anastomosis veins have often been confused as RAVs, and even a strong focal contrast effect in the adrenal parenchyma adjacent to inferior vena cava (IVC), especially on thin slices and in the arterial phase, can mimic a short RAV. Therefore, in this study, we determined DRAVs as two RAVs separately drained into IVC or accessory hepatic vein directly by venography as depicted in a previous study of surgical anatomy (17). There were numerous venous networks around the adrenal gland (18, 19), and adrenal venography often showed the anastomosis veins, including the renal capsular vein, which connected to the renal vein, gonadal vein, IVC remote from the adrenal gland, or others but we did not include those. If tributaries branched over the whole adrenal gland from one RAV, we did not try to cannulate the other vein and collect blood, as we deemed it to be unnecessary. If there was a lack of contrast-enhanced areas or tributaries in accordance with the other RAV, we tried to sample the other.

Analysis of DRAVs

The authors included cases involving DRAVs by reviewing the venography images and radiologist's procedural reports of sAVS. Two RAVs were defined as main or accessory by venography; the main had a broader drainage area, and the accessory had a smaller drainage area (Fig. 1a). We also examined the presence of other RAV delineations by the contrast material injection from one RAV and a recognizable direct anastomosis vein between two RAVs on venography.

The diameter of DRAVs was measured on right anterior oblique view venography and was qualitatively compared on CT in the late arterial phase. The diameter of adrenocortical adenoma was measured on CT.

The length of the right adrenal glands in craniocaudal or left–right direction was measured on CT. Further, the length from RAVs to the right adrenal caudal edge or right edge was measured. The relative craniocaudal or left–right intra-adrenal position was calculated as the ratio of the former to the latter (Fig. 1b, 1c). The relationship between the vertebral body and the craniocaudal position of the RAV's orifice into the IVC or hepatic vein was also examined.

We divided the right adrenal gland into three segments (i.e., superior, lateral, and inferior) and described the drainage area of each RAV according to venography. When either RAV was not cannulated, its drainage area was estimated by the venogram from the other RAV. The success of catheter cannulation and RAV sampling was examined.

Catheterization of RAVs was confirmed by selectivity index (SI), which is the ratio of plasma cortisol concentration (PCC) in the adrenal vein to that in the external iliac vein. The plasma aldosterone concentration (PAC), PCC, and aldosterone/cortisol (A/C) ratio after cosyntropin stimulation were compared between the main and accessory RAVs. The ratio of the higher side to the lower side was calculated.

The lateralization index (LI), defined as the ratio of the A/C on the dominant and nondominant sides, was calculated for both RAVs. On the left side, the LI values of the left ACV or common trunk were used according to the guidelines (1, 2). The treatment plans were clinically decided based on sAVS findings, but those based on the cAVS between both RAVs were compared with cases involving sampling from both using the LI. LI >4 reflected a unilateral lesion and an indication for surgery, while LI ≤4 reflected a bilateral lesion and an indication for medication (24–26). In cases of concurrent CPA and APA,

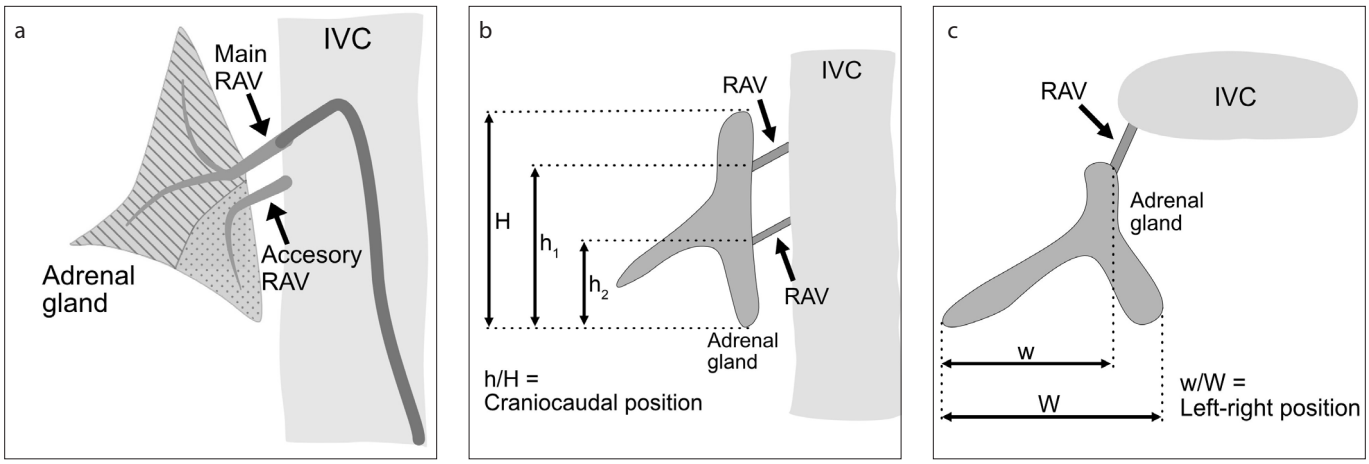

Figure 1. a–c. Definition and position of the duplicated right adrenal veins. Schematic drawing of duplicated RAVs in the right anterior oblique view **(a)** reveals the cranial RAV as a main RAV with a large drainage area *(shaded)* and the caudal RAV as an accessory RAV with a smaller drainage area *(dotted)*. Panel **(b)** shows the craniocaudal position defined as the length between the adrenal caudal edge and adrenal vein attachment (h_1, h_2) divided by the adrenal craniocaudal length (H). Panel **(c)** shows the left–right position defined as the length between the adrenal right edge and adrenal vein attachment (w) divided by the adrenal left–right length (W). RAV, right adrenal vein; IVC, inferior vena cava.

Table 1. Demographic and endocrine data in 14 patients

Parameters	Data
Age (years)	46.3±9.9
Sex (male, female)	10, 4
Baseline	
Plasma aldosterone (pg/mL)	174 (120–334)
Plasma renin activity (ng/mL/h)	0.3 (0.2–0.6)
ARR (pg/mL, per ng/mL/h)	420 (269–938)
Captopril-challenged ARR (pg/mL, per ng/dL/h)	449 (237–1112)
K (mEq/L)	3.6±0.4
SBP (mmHg)	130±15
DBP (mmHg)	86±13
HR (beats/min)	77±16
Number of antihypertensive drugs	1±0.8
Creatinine (mg/dL)	0.81±0.17
eGFR (mL/min/1.73 m^2)	78.8±16.5

Data are shown as mean±standard deviation or as median (interquartile range).
ARR, aldosterone/renin activity ratio; SBP, systolic blood pressure; DBP, diastolic blood pressure; HR, heart rate; eGFR, estimated glomerular filtration rate.

we used the PAC ratio instead of the LI using the same cutoff value to assess the treatment plan and to prevent the effects of PCC (27). In addition, we compared the cAVS and sAVS-based diagnoses in terms of whether surgery was indicated or not.

The Wilcoxon rank-sum test was used to compare the diameter, intra-adrenal relative position, values of the PAC, PCC, and A/C of DRAVs. *p* values <0.05 were considered to be indicative of statistical significance. JMP pro version 15.0.0 software (SAS Institute Inc.) was used for statistical analysis.

Results

A total of 436 patients underwent sAVS. Four patients were excluded for lack of venography at the RAV: three due to technical failures and one due to previous right adrenalectomy. Fourteen (3.2%) out of 432 patients were diagnosed with DRAVs by venography. The patients' demographic data, CT, and some venography and CT images are shown in Table 1, Figs. 2 and 3. No patient experienced a major complication.

Catheter cannulation and blood sampling were performed in the main RAV, left adrenal central vein, and tributaries in all 14 patients. Ten patients were cannulated in the accessory RAV, and eight had successful sampling and two could not be sampled. The SI of RAV was ≥10.8 in 13 patients and that of left ACV was ≥14 in all patients, which indicated successful catheterization (1, 28). In one patient, the PCC in RAV and right tributaries was low because of suppression due to the contralateral CPA causing subclinical Cushing's syndrome, but the cannulation was thought to be successful. Thus, the technical success rate of both cAVS and sAVS in these patients were 100%.

Venograms were obtained from both RAVs in 10 cases. In four cases, venograms from an accessory side could not be obtained because an accessory vein was not recognized during the procedure and recognized after it (n=2) and because all segmental blood had been sampled from the main side, thereby, not requiring catheter cannulation (n=2).

In all cases, contrast in at least one RAV delineated the other RAV. In 12 of 14 cases, apparent anastomoses between DRAVs were delineated in the second- or higher-order tributaries but not in 2 cases.

Adrenocortical adenomas were detected in 11 patients and were located on the right in four patients, on the left in three patients, and on both sides in four patients. The mean diameter of the adrenocortical adenomas was 10±4.44 mm.

On venography, mean diameter of the main side RAV was 3±0.63 mm and that of the accessory side RAV was 2.1±0.41 mm. All main veins were thicker than the other veins, and the diameter between the main

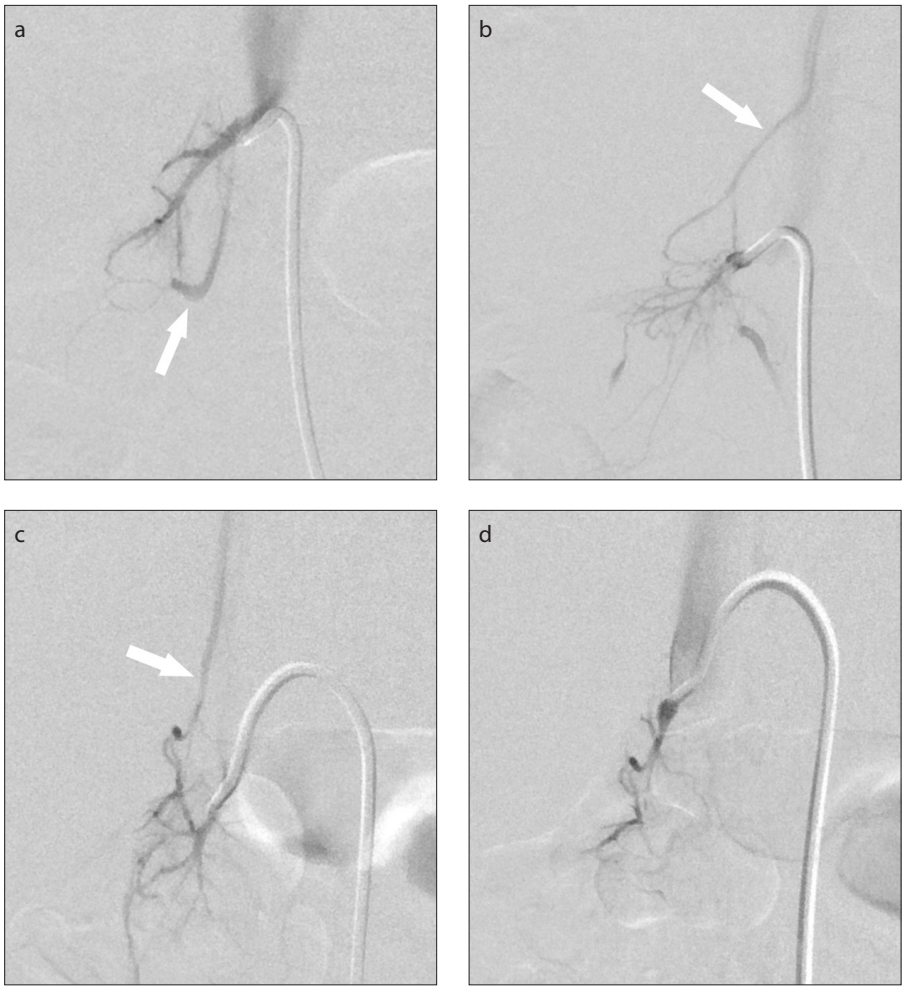

Figure 2. a–d. Venography images of the duplicated right adrenal veins of case 1 **(a, b)** and case 2 **(c, d)**. Digital subtraction venography images in oblique view obtained with injection into the right adrenal vein (RAV) of the main **(a, c)** and accessory **(b, d)** sides. The cranial vein is main in case 1, whereas the caudal vein is main in case 2. Contrast from one vein to the other *(arrow)* is depicted via anastomosis.

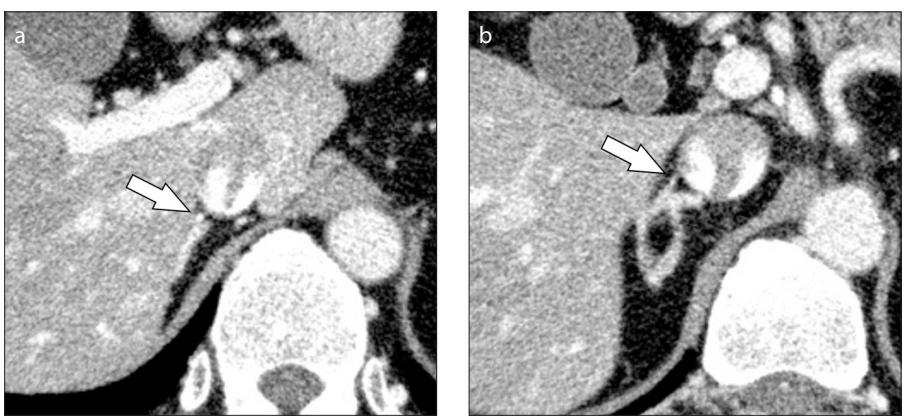

Figure 3. a, b. CT images of the duplicated right adrenal veins. CT image of case 1 with two right adrenal veins *(arrow)* clearly delineated in the axial view. The cephalic main vein is relatively thicker **(a)**, whereas the caudal accessory vein is relatively thinner **(b)**.

and accessory adrenal veins was significantly different ($p < 0.001$) (Fig. 4a). On contrast-enhanced CT, all DRAVs were detectable and the diameters appeared to be the same in 4 patients and different in 10, as per qualitative analysis.

The mean craniocaudal length of the right adrenal gland on CT was 43.7±6.40 mm. The mean craniocaudal length and the relative position were 28.6±7.49 mm and 65.5%±16.0%, respectively, from the main RAV to the adrenal caudal edge and were 21.1±7.89 mm and 48.1%±16.8%, respectively, from the accessory RAV. In 11 patients, the main RAV was on the cranial side. The main RAV was more cranially located ($p = 0.007$) (Fig. 4b). The mean left–right length of the right adrenal gland was 23.9±5.51 mm. The mean left–right length and relative position were 15.1±3.70 mm and 63.8%±9.8%, respectively, from the main RAV to the right edge and 14.4±3.89 mm and 60.7%±11.8%, respectively, from the accessory RAV. The left–right positions of the RAVs were not significantly different ($p = 0.41$) (Fig. 4c). The relationship between the vertebral body and RAV's orifice into the IVC or accessory hepatic vein is shown in Fig. 4d.

The drainage areas of accessory RAVs were the superior segment in two cases and the inferior segment in 10 cases, respectively. Drainage areas of the main RAVs were the other segments, such as lateral and inferior segments or superior and lateral segments. In two cases, all segmental blood was drained into the main RAV.

Data of eight patients who were sampled in both RAVs are shown in the Table 2. The median PAC, PCC, and A/C in the main RAV of eight patients were 23,100 pg/mL (range, 3060–157,900 pg/mL), 803 µg/dL (range, 56–1926 µg/dL), and 19.9 (range, 3.94–1203), respectively. The median PAC, PCC, and A/C in the accessory vein were 10,640 pg/mL (range, 3040–88,200 pg/mL), 618 µg/dL (range, 68–1328 µg/dL), and 21.4 (range, 3.00–193), respectively.

A comparison of the main and accessory veins in eight patients showed that PAC, PCC, and A/C were not significantly different ($p = 0.17$, 0.53, and 0.83, respectively). The median of PAC, PCC, and A/C higher side divided by lower side, were 3.93 (range, 1.01–11.1), 1.86 (range, 1.11–3.25), and 2.78 (range, 1.20–23.7), respectively.

Based on sAVS findings, three patients were diagnosed with right APA, one with a right APmicroA and left CPA, two with bilateral APAs, and seven with IHA. The diagnoses based on cAVS and sAVS in eight patients with both RAVs sampled are shown in Fig. 5. The cAVS diagnoses between both RAVs were the same in six of eight patients that had samples from both RAVs. However, the remaining two were changed from right unilateral to bilateral and were two of four

Table 2. Adrenal venous sampling findings in 8 patients with duplicated right adrenal veins

Case	Age (y)/ Sex	Adrenal tumor side	RAV, main and accessory			LAV, COM			LI, RAV vs.		cAVS diagnosis	Right tributary with max PAC			Left tributary with max PAC			sAVS diagnosis
			PAC (pg/mL)	PCC (µg/dL)	A/C	PAC (pg/mL)	PCC (µg/dL)	A/C	LAV	COM		PAC (pg/mL)	PCC (µg/dL)	A/C	PAC (pg/mL)	PCC (µg/dL)	A/C	
A	57/M	Right	22300	1926	11.6	3550	1218	2.91	3.97	3.07	Bilateral PA[c]	9640	1467	6.57	3340	1096	3.05	Right APA
			88200	608	145	3910	1037	3.77	49.8	38.5	Right unilateral PA							
B	36/M	Right	31900	830	38.4	5480	820	6.68	5.75	3.19	Right unilateral PA	47600	921	51.7	6120	1680	3.64	Right APA
			8150	255	32.0	2190	182	12.0	4.78	2.66	"							
C	60/M	Right	157900	295	535	2360	447	5.28	101	106	Right unilateral PA	126984	369	344	2070	537	3.85	Right APA
			14200	629	22.6	908	180	5.04	4.28	4.48	"							
D	50/F	Left	67400	56	1204	11400	640	17.8	5.91[a]	9.68[a]	Right unilateral PA	64000	91	707	10600	995	10.7	Right APmicroA
			13100	68	193	6960	1084	6.42	1.15[a]	1.88[a]	Bilateral PA[c]							with left CPA
E	42/M	Left	3060	776	3.94	172758	750	230	58.4[b]	30.2[b]	Left unilateral PA	4970	1011	4.92	259625	970	267	Left APA
			3040	1013	3.00	63900	536	119	76.8[b]	39.7[b]	"							
F	34/F	None	4240	671	6.32	18400	985	18.7	2.96[b]	3.75[b]	Bilateral PA	22900	1085	21.1	19300	921	21.0	IHA
			17700	1067	16.6	7890	333	23.7	1.13	1.43[b]	"							
G	56/M	Bilateral	23700	966	24.5	9230	820	11.3	2.18	1.16	Bilateral PA	45700	1000	45.7	29900	897	33.3	IHA
			8180	404	20.2	14600	689	21.2	1.80	1.5[b]	"							
H	34/M	Right	22500	1471	15.3	16900	1381	12.2	1.25	1.22	Bilateral PA	35700	1743	20.5	19700	1287	15.3	IHA
			6940	1328	5.23	10900	869	12.5	2.34[b]	2.4[b]	"							

For items with two levels of RAV, LI, and cAVS diagnosis, the upper and lower values indicate the values of main and accessory RAV, respectively. For items with two levels of LAV and COM, the upper and lower values indicate the values of LAV and COM, respectively.
RAV, right adrenal vein; LAV, left adrenal central vein; COM, common trunk; LI, lateralization index; PAC, plasma aldosterone concentration; PCC, plasma cortisol concentration; A/C, aldosterone/cortisol ratio; cAVS, conventional adrenal venous sampling; sAVS, segmental adrenal venous sampling; PA, primary aldosteronism; APA, aldosterone-producing adenoma; APmicroA, aldosterone-producing microadenoma; CPA, cortisol-producing adenoma; IHA, idiopathic hyperaldosteronism.
[a]The absolute ratio of PACs is given because it is more appropriate than LI for a cortisol-producing adenoma.
[b]Predominance on the left side.
[c]Patients receiving different treatment strategy based on cAVS and sAVS diagnosis.

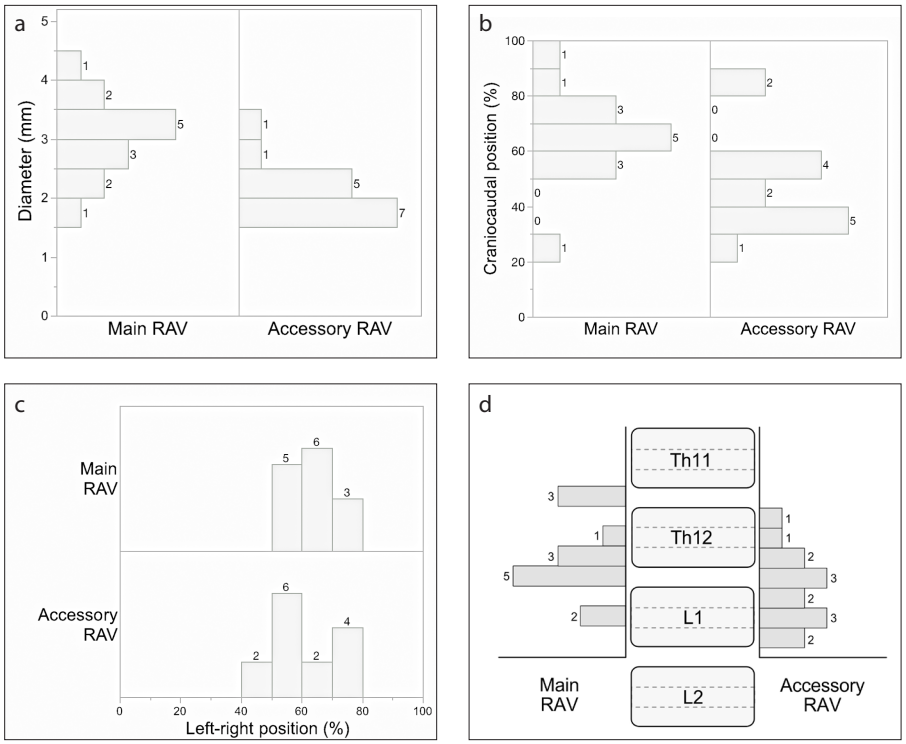

Figure 4. a–d. Diameter, craniocaudal, and left–right position of the duplicated right adrenal veins. Panel **(a)** shows the diameter of main or accessory RAVs. The diameter between the main and accessory adrenal veins was significantly different. Panels **(b, c)** show craniocaudal and left–right position of duplicated RAVs. The main vein was significantly located more cranially. The left–right positions of the RAVs were not significantly different. Panel **(d)** shows the craniocaudal levels of RAV orifices relative to vertebral bodies based on CT imaging.

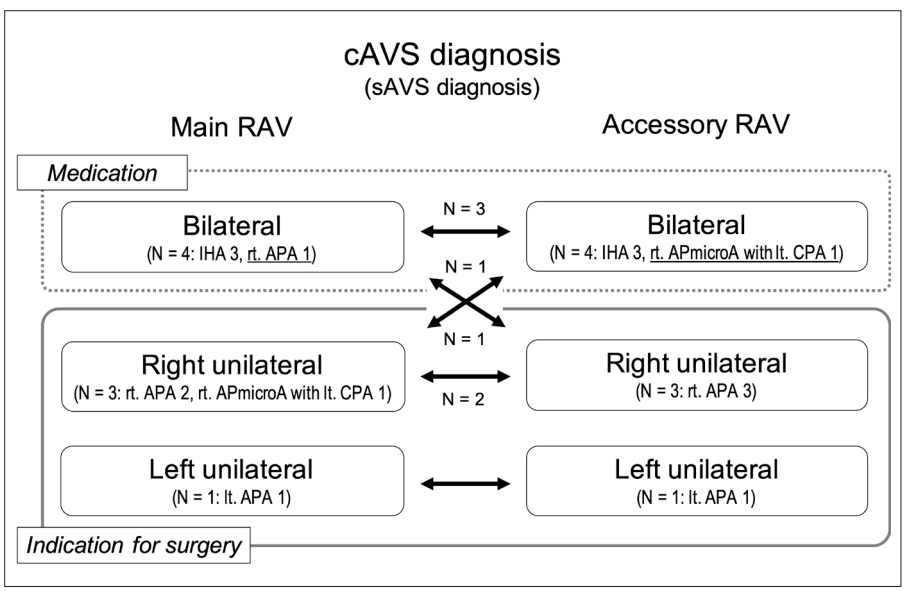

Figure 5. Difference of adrenal venous sampling diagnosis between duplicated right adrenal veins. Left and right columns show conventional adrenal venous sampling (cAVS) diagnoses of main and accessory right adrenal veins based on a lateralization index or aldosterone concentration ratio (cutoff of 4 after cosyntropin stimulation). The numbers and segmental adrenal venous sampling (sAVS) diagnosis are shown in parentheses. The difference in the treatment strategy between cAVS and sAVS diagnosis is underlined. In two of eight cases, the diagnosis was changed between right unilateral and bilateral, whereas the diagnosis was not changed in six cases by cAVS. RAV, right adrenal vein; IHA, idiopathic hyperaldosteronism; APA, aldosterone-producing adenoma; APmicroA, aldosterone-producing microadenoma; CPA, cortisol-producing adenoma.

patients with a right APA or APmicroA. One patient had a right APA with an LI of 3.97 or 49.8 using the left ACV value and an LI of 3.07 or 38.5 using the common trunk value. The other had a right APmicroA accompanied by a left CPA with a PAC ratio of 5.91 or 1.15 using the left ACV value and 9.68 or 1.88 using the common trunk value. Conversely, the treatment plan of all four patients with left APA or IHA was not changed. The treatment plan based on sAVS differed from that based on cAVS in either RAV (one patient each).

Discussion

Some anatomical variations of RAVs, including duplication and triplication, were previously reported because variations may have a higher risk of surgical complications (15–19, 29). In a report of a large series of laparoscopic adrenalectomies for various diseases, the prevalence of adrenal venous anomaly was 70 of 546 (13%) in total and 42 of 250 (17%) on the right (17). The prevalence was high in cases with high vascularity tumors, such as pheochromocytoma. Eight of 170 (4.7%) with hyperaldosteronism, five on the right, had variants including four duplications and one triplication. The veins were considered to be surgically distinct, >2–3 mm in diameter, and their definition of thickness may be close to the one in our study. The exact prevalence of DRAVs was not mentioned, but it appeared to be similar.

Meanwhile, frequent multiple adrenal veins were reported in cadaver studies: 13 duplications and 5 triplications of RAV in 45 specimens (18, 19). The incidence was higher than that observed in surgical analysis and in this study, which may be attributed to different examination methods.

Adrenocortical adenomas on the right side were seen in eight patients but were absent in six patients; therefore, DRAVs were not exclusive in PA patients with a right adrenal mass.

Mapping CT of the RAV has been shown to be important for the procedural success of AVS, and various studies have reported that the detection rates were high (13, 30). To our knowledge, DRAVs have been described only in few references and one case report related to AVS (20–22). Although DRAVs were identified in some cases on contrast CT (Fig. 3), in practice, periadrenal veins and even heterogeneous adrenal contrast may often be confused with short RAV.

Therefore, in many cases, accurate diagnosis of DRAVs was difficult by CT alone and required venography.

The intra-adrenal relationship of DRAVs had not been clear previously. Our study found that DRAVs could be classified into main and accessory veins by considering the drainage area and that the main vein was thicker on venography. The mean diameter of the RAV was 3.5 mm (range, 2–6) and 3±1.19 mm in cadaver studies (19, 20). The mean diameter of the main RAV was comparable with the previous studies, but that of the accessory RAV was thinner in our study. In some cases, contrast-enhanced CT also showed that the main RAV was thicker compared with the accessory RAV. In addition, it was often located cranially. These CT findings may be helpful in predicting the main side.

The difficulty of sampling in the main RAV was not much; however, attempts to sample in the thin accessory RAV on the right side might be unsuccessful, as sampling in the accessory RAV was impossible in two out of ten patients included in this study.

In eight patients, sampling was successful at both RAVs. There were no significant differences in the PAC, PCC, and A/C between the main and accessory veins, although the ratio of high to low varied and the number of cases were small. Among eight patients, the treatment plan according to diagnosis by cAVS differed between both RAVs in two patients but was the same in six patients. The former two patients were among the four with right APA based on sAVS, and it seemed to lead to inappropriate patient management. In contrast, one with left APA and three with IHA did not change their treatment plan. These results might suggest that blood sampling from one RAV was sufficient in many patients; however, blood collection from both sources may be desirable, especially in patients with right APA.

Sampling in the accessory RAV may also be desirable if there is a lack of description of segmental tributaries from the main RAV using venography. Potential anastomoses in the intra- and extra-adrenal veins were shown in a cadaver study (19). The venogram from one RAV could reveal the anastomosis vein, and taking a closer look might be helpful when cannulating the other RAV. However, identifying the adrenal vein may be difficult on a venogram of the accessory RAV alone (Fig. 2). No major complication occurred, but a gentle procedure to sample the thin accessory veins is recommended to avoid iatrogenic injury.

This report has some considerable limitations. We determined DRAVs referring to venography and potentially missed few DRAVs due to insufficient contrast injection. The authors did not include periadrenal thick meandering vessels, including the renal capsular vein, as a minor RAV because those primarily indicate the prominent anastomotic veins.

The authors used cosyntropin stimulation results for AVS-based diagnosis but the use remains controversial. LI > 4 is used as a parameter for unilateral PA in most centers; however, some studies used LI >3 or 2; therefore, LI ≥2 or ≤4 should be interpreted with caution (25, 26, 31). Even in the present study, the use of these permissive criteria result in different treatment strategies based on cAVS diagnosis in majority of the cases. In clinical practice, the treatment plan would be decided comprehensively considering various factors, such as age, hypokalemia, adrenal mass, and contralateral suppression.

In one report on CPA, PAC values were directly compared so that the cortisol levels would not affect the diagnosis of aldosterone laterality (27). In this study, the same cutoff was used in patients without CPA. However, this remains to be a subject of discussion and has not been studied in many cases.

We also highlight the value of tributary blood collection for sAVS-based diagnosis, which has the advantage of recognizing the heterogeneity of intra-adrenal hormone secretion that allows the diagnosis of bilateral APA. Such a diagnosis is not possible by cAVS, which reportedly increases the indication for surgery (7–11). However, this issue is still a matter of debate.

In conclusion, DRAVs were rare, with the main side being thicker and more cranially located. Depending on blood sampled from either of DRAVs, the diagnosis of cAVS remained same in many patients, but might change from surgery to medication in some cases, especially with right APA. Therefore, recognition of DRAVs is important to make accurate subtype diagnosis of PA by AVS.

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Conflict of interest disclosure

The authors declared no conflicts of interest.

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