ORIGINAL ARTICLE

Variant Adrenal Venous Anatomy in 546 Laparoscopic Adrenalectomies

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Importance: Knowing the types and frequency of adrenal vein variants would help surgeons identify and control the adrenal vein during laparoscopic adrenalectomy.

Objectives: To establish the surgical anatomy of the main vein and its variants for laparoscopic adrenalectomy and to analyze the relationship between variant adrenal venous anatomy and tumor size, pathologic diagnosis, and operative outcomes.

Design, Setting, and Patients: In a retrospective review of patients at a tertiary referral hospital, 506 patients underwent 546 consecutive laparoscopic adrenalectomies between April 22, 1993, and October 21, 2011. Patients with variant adrenal venous anatomy were compared with patients with normal adrenal venous anatomy regarding preoperative variables (patient and tumor characteristics [size and location] and clinical diagnosis), intraoperative variables (details on the main adrenal venous drainage, any variant venous anatomy, duration of operation, rate of conversion to hand-assisted or open procedure, and estimated blood loss), and postoperative variables (transfusion requirement, reoperation for bleeding, duration of hospital stay, and histologic diagnosis).

Intervention: Laparoscopic adrenalectomy.

Main Outcomes and Measures: Prevalence of variant adrenal venous anatomy and its relationship to tumor characteristics, pathologic diagnosis, and operative outcomes.

Results: Variant venous anatomy was encountered in 70 of 546 adrenalectomies (13%). Variants included no main adrenal vein identifiable (n=18), 1 main adrenal vein with additional small veins (n=11), 2 adrenal veins (n=20), more than 2 adrenal veins (n=14), and variants of the adrenal vein drainage to the inferior vena cava and hepatic vein or of the inferior phrenic vein (n=7). Variants occurred more often on the right side than on the left side (42 of 250 glands [17%] vs 28 of 296 glands [9%], respectively; $P=.02$). Patients with variant anatomy compared with those with normal anatomy had larger tumors (mean, 5.1 vs 3.3 cm, respectively; $P<.001$), more pheochromocytomas (24 of 70 [35%] vs 100 of 476 [21%], respectively; $P=.02$), and more estimated blood loss (mean, 134 vs 67 mL, respectively; $P=.01$). For patients with variant anatomy vs those with normal anatomy, the rates of transfusion requirement (2 of 70 [3%] vs 10 of 476 [2%], respectively; $P=.69$) and reoperation for bleeding (1 of 70 [1%] vs 3 of 476 [1%]; $P=.46$) were similar between groups.

Conclusions and Relevance: Understanding variant adrenal venous anatomy is important to avoid bleeding during laparoscopic adrenalectomy, particularly in patients with large tumors or pheochromocytomas. Surgeons should anticipate a higher probability of adrenal vein variants when operating on pheochromocytomas and larger adrenal tumors.

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LAPAROSCOPIC ADRENALECTOMY has evolved to become the procedure of choice for most surgically treated adrenal diseases.[1-3] A safe laparoscopic adrenalectomy requires a thorough knowledge of the usual anatomy of the adrenal gland as well as its unusual anatomical variations.

The venous drainage from each adrenal gland, described in standard anatomical texts, is usually via a single vein emptying directly into the inferior vena cava on the right side, joining with the inferior phrenic vein, and then draining into the left renal vein on the left (**Figure 1** and **Figure 2**).[4] Variations to this pattern have been documented in cadaver studies,[5-11] a clinical study,[12] and a few case reports.[13,14]

See Invited Critique at end of article

Anson and Caudwell[5] studied the venous drainage of the adrenal glands in 450 cadavers. They confirmed the constancy of conventional venous drainage anatomy, with only 1 variant identified in 900 adrenals. Subsequent cadaver studies de-

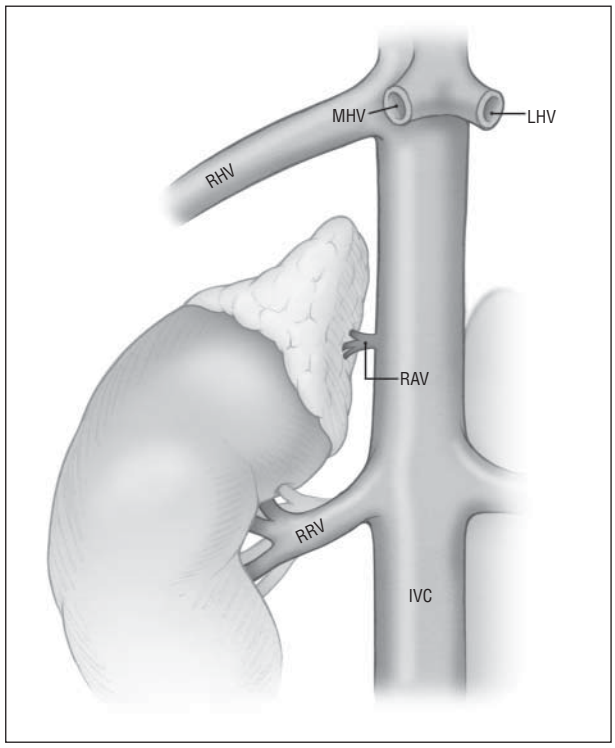

Figure 1. Normal adrenal venous anatomy on the right side. IVC indicates inferior vena cava; LHV, left hepatic vein; MHV, middle hepatic vein; RAV, right adrenal vein; RHV, right hepatic vein; and RRV, right renal vein.

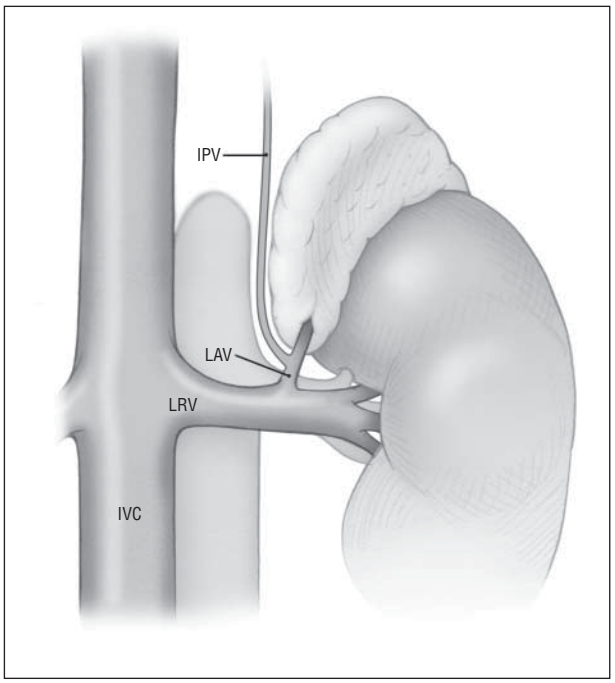

Figure 2. Normal adrenal venous anatomy on the left side. IPV indicates inferior phrenic vein; IVC, inferior vena cava; LAV, left adrenal vein; and LRV, left renal vein.

scribed more variations in the adrenal veins, mainly on the right side.[6-11] These cadaver studies reported the anatomy of nondiseased adrenal glands. Adrenal pathology, possibly through angiogenesis or vasodilation of preexisting small collateral vessels, may increase both the variation of venous drainage and the number of periadrenal vessels. Parnaby et al[12] studied the venous anatomy encountered in 162 laparoscopic adrenalectomies for adrenal pathology. They found variant venous anatomy in 5 adrenal glands: 4 in patients with pheochromocytoma and 1 in a patient with adrenal cortical cancer. In addition, MacGillivray et al[13] reported confluence of the right adrenal vein with the accessory right hepatic vein in a patient with hyperaldosteronism, and Stack et al[14] described an anomalous left adrenal vein draining directly into the inferior vena cava in a patient with hyperaldosteronism.

The ability to anticipate variant adrenal venous anatomy is important to prevent excessive bleeding from the adrenal and accessory veins during laparoscopic adrenalectomy. We therefore studied 546 consecutive laparoscopic adrenalectomies to establish details of the primary venous drainage and any variant venous anatomy. In addition, we compared patients with variant adrenal venous anatomy with patients with normal adrenal venous anatomy.

METHODS

With approval of the University of California, San Francisco Institutional Review Board, we retrospectively reviewed the records of all patients (n = 523) who underwent consecutive laparoscopic adrenalectomy performed by a single surgeon at the University of California, San Francisco and the San Francisco Veterans Affairs Medical Center between April 22, 1993, and October 21, 2011.

With the exception of 19 cases performed via a retroperitoneal approach, all operations were performed via the lateral transperitoneal approach.

Adrenal vascular anatomy was routinely recorded prospectively by the attending surgeon in the operative findings part of the detailed operative report. Only patients with such a report describing the venous anatomy were included. We reviewed these operative notes to assess variant adrenal venous anatomy. Sufficient information was available for 506 patients. Forty of these patients underwent bilateral adrenalectomy, yielding a total of 546 procedures evaluable for adrenal venous anatomy.

Preoperative data included patient and tumor characteristics (size and location) and clinical diagnosis. Intraoperative data included the details on the main adrenal venous drainage, any variant venous anatomy, duration of operation, rate of conversion to hand-assisted or open procedure, and estimated blood loss. Postoperative data included transfusion requirement, reoperation for bleeding, duration of hospital stay, and histologic diagnosis.

Patients with variant adrenal venous anatomy were compared with patients with normal adrenal venous anatomy regarding the various preoperative, intraoperative, and postoperative variables. Comparison of binary variables was by χ^2 test. Comparison of continuous values was by unpaired t test. Descriptive statistics were calculated for all variables. Statistical significance was shown at $P < .05$.

RESULTS

In 70 (13%) of the 546 evaluable procedures (250 [46%] right-sided procedures and 296 [54%] left-sided procedures), there was a variant adrenal venous anatomy

Table 1. Variant Adrenal Venous Anatomy by Number

Variant	Patients, No. (n = 63)
No central adrenal vein identified	18
With multiple small veins	7
1 Central adrenal vein with multiple small veins	11
2 Adrenal veins	20
With multiple small veins	2
>2 Adrenal veins	14
With multiple small veins	1

Table 2. Variant Adrenal Venous Anatomy by Location

Side	Variant (n = 7)
Left	Central adrenal vein, 2 branches (n = 1)
	Central adrenal vein draining into left renal vein, branch to inferior phrenic vein (n = 1)
	Central adrenal vein, inferior phrenic vein draining separately into left renal vein (n = 2)
Right	Central adrenal vein draining into right hepatic vein (n = 1)
	Central adrenal vein draining into right hepatic vein, multiple small veins draining into inferior vena cava (n = 1)
	Central adrenal vein draining into inferior vena cava, accessory adrenal vein draining into right hepatic vein (n = 1)

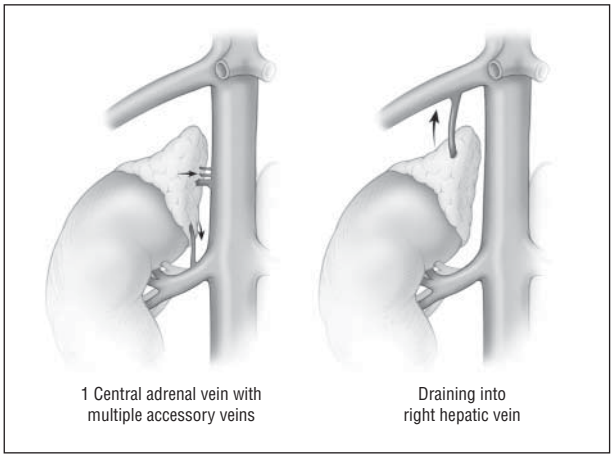

Figure 3. Variant adrenal venous anatomy on the right side.

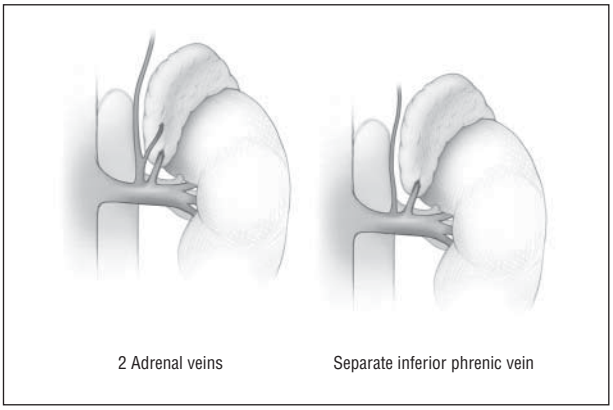

Figure 4. Variant adrenal venous anatomy on the left side.

(**Table 1**, **Table 2**, **Figure 3**, and **Figure 4**). Variants can be related to the number of veins and/or the location of the adrenal vein. Eighteen patients had no single adrenal vein identifiable, 11 had 1 central adrenal vein with additional but significant small veins, 20 had 2 adrenal veins, and 14 had more than 2 adrenal veins. Seven patients had a variant of the adrenal vein in relation to the hepatic vein and inferior vena cava or to the inferior phrenic vein. Venous variants occurred more often on the right side than on the left side (42 of 250 [17%] vs 28 of 296 [9%], respectively; $P = .02$).

Patients with variant anatomy compared with those with normal venous anatomy (**Table 3**) had larger tumors (mean, 5.1 vs 3.3 cm, respectively; $P < .001$), more pheochromocytomas (24 of 70 [35%] vs 100 of 476 [21%], respectively; $P = .02$), and more bilateral adrenalectomies (13 of 70 [19%] vs 27 of 476 [6%], respectively; $P < .001$). The mean operative time was longer for the variant group than for the group with normal venous anatomy (right side: 2.62 vs 2.32 hours, respectively; $P = .03$; left side: 2.99 vs 2.50 hours, respectively; $P = .007$). The group with variant anatomy compared with those with normal anatomy had more intraoperative estimated blood loss (mean, 134 vs 67 mL, respectively; $P = .01$), although the transfusion rate was similar (2 of 70 [3%] vs 10 of 476 [2%], respectively; $P = .69$). Reoperation for bleeding was required in 1 patient (1%) with variant anatomy and 3 patients (1%) with normal anatomy ($P = .46$). In the variant group, 1 patient with adrenal metastases required conversion to an open procedure due to adhesion of the tumor to the inferior vena cava and bleeding from parasitic vessels. One patient had conversion to an open procedure owing to adhesions and 1 patient had conversion to a hand-assisted procedure owing to large tumor size and adhesions. In the group with normal venous anatomy, there were 11 conversions (2%). These were due to tumor adhesion to or invasion in surrounding tissue (n = 7), bleeding (n = 2), and tumor size (n = 2).

Sixteen variants (3 left-sided, 13 right-sided) occurred in patients with bilateral disease: 2 of 21 patients with bilateral pheochromocytoma and 14 of 17 patients with bilateral hypercortisolism. Three patients had bilateral variant venous anatomy. These included no adrenal vein identifiable bilaterally, bilateral duplication of the adrenal vein, and duplication of the left adrenal vein and triplication of the right adrenal vein. Two of these patients had bilateral cortical hyperplasia due to ectopic corticotropin production and 1 had pituitary Cushing syndrome.

In the variant group, 2 patients histologically had 2 separate tumors in a single adrenal gland. There was 1 case of Cushing carcinoma with a myelolipoma and 1 case of a cortical adenoma with a myelolipoma.

Patients with variant anatomy and hypercortisolism most often had either no single adrenal vein identifiable (n = 9) or duplication of the adrenal vein (n = 6) as the

Table 3. Normal vs Variant Adrenal Venous Anatomy

Variable	Adrenal Venous Anatomy		*P* Value
	Normal (n = 476)	Variant (n = 70)	
Age at surgery, mean, y	49.9	50.0	.49
Female, No. (%)	266 (56)	35 (50)	.43
Diagnosis, No. (%)			
Hyperaldosteronism	162 (34)	8 (12)	<.001
Pheochromocytoma	100 (21)	24 (35)	.01
Metastasis	38 (8)	5 (7)	.85
Hypercortisolism	101 (21)	17 (25)[a]	.67
Cortical cancer	1 (0.2)	0	.70
Other	77 (16)	14 (21)[b]	.19
Tumor size, mean, cm	3.3	5.1	<.001
Adrenalectomy, No. (%)			.02
Right	208 (44)	42 (60)	
Left	268 (56)	28 (40)	
Duration of operation, mean, h			
Right	2.32	2.62	.03
Left	2.50	2.99	.007
Intraoperative bleeding complications, No. (%)	2 (0.4)	1 (1)	.84
Conversion, No. (%)	11 (2)	3 (4)	.57
Estimated blood loss, mean, mL	67	134	.01
Transfusion, No. (%)	10 (2)	2 (3)	.69
Reoperation for bleeding, No. (%)	3 (1)	1 (1)	.46
Duration of hospital stay, mean, d	2.0	2.6	.04

[a] One cortisol-producing carcinoma.
[b] Nonfunctioning adenoma/hyperplasia (n = 10), cyst (n = 3), myelolipoma (n = 1), angiomyelolipoma (n = 1), and neurofibroma (n = 1).

variant identified in their adrenal venous anatomy. Most of these patients also had enlarged, inflamed, atrophic, or, rarely, hypoplastic glands found during operation.

Patients with variant anatomy and pheochromocytoma had either duplication (n = 5) or triplication (n = 6) of their adrenal vein or had multiple small adrenal veins instead of (n = 2) or in addition to (n = 9) a single adrenal vein. One patient had 4 adrenal veins and 1 patient had more than 5 adrenal veins, draining into the inferior vena cava, the lumbar veins, and the hepatic veins.

Variants in patients with hyperaldosteronism occurred in 3 left and 5 right adrenal glands. These variants included duplication (n = 4) and triplication (n = 1) of the adrenal vein and variants involving the hepatic vein (n = 2) or inferior phrenic vein (n = 1).

We also performed a subgroup analysis excluding the 19 patients who underwent laparoscopic adrenalectomy performed via a retroperitoneal approach. This analysis showed no differences in results (data not shown).

DISCUSSION

Each adrenal gland is typically drained by a single vein emptying directly into the inferior vena cava on the right side, joining with the inferior phrenic vein, and then draining into the left renal vein on the left.[4] Identification and control of the adrenal vein are critical steps in laparoscopic adrenalectomy. However, few clinical studies report data on variants in the adrenal venous anatomy. There are also no clinical studies reporting the relationship between variant adrenal venous anatomy and tumor size or pathologic disease. To our knowledge, this is the first report of data on variant adrenal venous anatomy in a large series of laparoscopic adrenalectomies showing an association of variant adrenal venous anatomy vs tumor size and pathology. We found variants of the adrenal venous anatomy in a significant percentage of patients (13%), particularly in patients with pheochromocytomas and large tumors.

Most previous reports on adrenal venous drainage are cadaver studies (**Table 4**). Anson and Caudwell[5] studied 450 cadavers and found variant anatomy in only 1 patient (where the left adrenal vein joined the right renal vein). However, they did not specify whether they had dissected the adrenal vein in all cadavers. They also did not comment on the presence or absence of multiple small veins surrounding the adrenal gland. Other, smaller cadaver studies on adrenal venous anatomy have found higher rates of variation of the adrenal venous anatomy.[6-11] Variants in these studies included both the number of veins draining the adrenal gland as well as the location of the adrenal vein in relation to the hepatic vein or inferior phrenic vein.

These autopsy studies, however, were performed on normal adrenal glands and not pathologic adrenal glands. Parnaby et al[12] studied adrenal vein anatomy in 162 pathologic adrenal glands. They found that only 5 patients (3%) had adrenal vein variants. These variants included duplication of the right (n = 2) and left (n = 3) adrenal veins and were present in patients with pheochromocytoma (n = 4) or adrenocortical carcinoma (n = 1). They also found that patients with pheochromocytoma had increased numbers of periadrenal vessels. Although this was a small series, it demonstrated a higher rate of adrenal

Table 4. Variant Adrenal Venous Anatomy in Literature

Source	Right/Left Adrenals, No.	Variant Venous Anatomy, No. (%)	
		Right	Left
Anson and Caudwell,[5] 1948[a]	450/450	0 (0)	1 (0.1)
Johnstone,[6] 1957[a]	10/10	5 (50)	1 (10)
Clark,[7] 1959[a]	16/16	10 (62)	5 (31)
Davidson et al,[8] 1975[a]	50/50	2 (1)	4 (2)
Nakamura and Tsuzuki,[9] 1981[a]	83/83	11 (13)	NA
El-Sherief,[10] 1982[a]	20/20	11 (55)	NA
Monkhouse and Khalique,[11] 1986[a]	45/57	18 (40)	NA
MacGillivray et al,[13] 1996	1/0	1 (NA)	0 (NA)
Stack et al,[14] 2001	0/1	0 (NA)	1 (NA)
Parnaby et al,[12] 2008	79/83	2 (1)	3 (2)
Current study, 2012	250/296	42 (8)	26 (5)

Abbreviation: NA, not applicable.
[a] Cadaver study.

vein variants in patients with pheochromocytoma ($P = .01$). We confirmed this finding, with variants occurring more often in patients with pheochromocytoma compared with other diagnoses. Twenty-four of the 124 patients (19%) with pheochromocytoma had variant adrenal venous anatomy. This may be explained by an increase in angiogenesis and vasculogenesis in pheochromocytoma.[15]

We had a subgroup of patients with no single identifiable adrenal vein. Their tumors obviously still had blood drainage, just from multiple small vessels. For this study, we defined "veins" operationally by their surgical significance for the conduct of the operation. What constitutes a vein is decided by the surgeon at the time of operation. In general, we cauterize small arteries or veins and we clip sizable veins. Veins in this study are usually at least 2 to 3 mm wide and are distinct.

We showed that some patients had multiple small veins draining into the inferior vena cava or renal vein, in addition to or instead of a main adrenal vein. Some even had multiple small veins in addition to 2 or 3 main adrenal veins. Small periadrenal veins may be collateral venous drainage pathways. The presence of multiple periadrenal veins has been reported before by others.[6,12] More collateral veins may become apparent as the tumor grows. This is consistent with our finding of larger tumors in patients with variant adrenal venous anatomy.

In our study and in previous studies,[6,7,10,11] variation in adrenal venous drainage occurred more often on the right side than on the left side. Previously reported variants of the left adrenal vein include duplication, with both the left adrenal vein and the inferior phrenic vein draining into the renal vein (n = 8)[7,12] or with 1 adrenal vein draining into the renal vein and 1 adrenal vein draining into the left lumbar vein (n = 1).[6]

We found 3 patients with variant anatomy of the right adrenal vein joining an (accessory) hepatic vein. This has been described in 1 case report by MacGillivray et al[13] and 3 cases reported by Johnstone[6] and was commented on in an editorial on minimal-access vs open adrenalectomy.[16] In a study focused on the anatomy of the hepatic veins and the vena cava, Nakamura and Tsuzuki[9] found that in 8 of 83 cadavers (10%), the right adrenal vein joined an accessory hepatic vein. We found one case of a duplicate right adrenal vein, one that drained into the vena cava, and another that joined an accessory hepatic vein. This was also found in 1 patient in the study by Nakamura and Tsuzuki. These data show that drainage of the right adrenal vein into an (accessory) hepatic vein may be a more common occurrence than is generally appreciated.

Laparoscopic right adrenalectomy, especially for larger tumors, requires extensive mobilization and medial retraction of the right lobe of the liver to expose the inferior vena cava and right adrenal vein. In patients with variant venous anatomy of the right adrenal gland, excessive retraction of the liver or rough dissection along the retrohepatic vena cava may injure a variant vein. Extra attention to the venous anatomy is advised during right adrenalectomy, especially for large tumors and pheochromocytoma.

We have addressed only the adrenal venous anatomy in this study. The adrenal arterial anatomy has been addressed in our prior study.[17] Adrenal arteries tend to be small and indistinct. They usually can be easily cauterized except for occasional large inferior arteries that need to be ligated with clips.

This study showed that the adrenal venous drainage including anatomical variants can be defined clearly during laparoscopic adrenalectomy. Because of magnification, laparoscopy provides better visualization of the adrenal anatomy. We show a similar rate of (bleeding) complications between patients with normal venous anatomy and those with variant adrenal venous anatomy. Only 1 patient with variant anatomy in our study needed conversion to an open procedure owing to invasion of the tumor into the inferior vena cava and bleeding from numerous parasitic veins. None of the 5 patients with variant adrenal venous anatomy in the study by Parnaby et al[12] had bleeding complications due to failure to identify or ligate the adrenal vein variants, and conversion was necessary in only 1 of their patients because of concern of invasion to the adjacent structure. Laparoscopic adrenalectomy is a safe procedure if the surgeon is aware of the possible anatomical venous variants.

We found no venous variants in 19 retroperitoneal adrenalectomies. It is possible that the adrenal venous anatomy is not seen as well during a retroperitoneal approach, but we do not have sufficient retroperitoneal cases to make a firm conclusion. Subgroup analysis excluding these 19 cases, however, did not change our overall findings and conclusions.

CONCLUSIONS

Variants in adrenal venous anatomy are commonly found during laparoscopic adrenalectomy. Understanding these variants is important to prevent bleeding from the adrenal and accessory veins during surgery, particularly in patients with large tumors or pheochromocytoma.

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