Supplementary Material and methods

Patients were enrolled from the following hospitals:
Two medical centers (National Taiwan University Hospital (NTUH), Taipei, Taiwan; Taipei Medical University Hospital, Taipei, Taiwan) and five regional hospitals (Cardinal Tien Hospital, New Taipei City, Taiwan; Taipei Tzu Chi Hospital, New Taipei City, Taiwan; Yun- Lin Branch of NTUH, Douliou City, Taiwan; Hsin-Chu Branch of NTUH, Hsin-Chu City, Taiwan; Zhongxing Branch of Taipei City Hospital, Taipei, Taiwan)[1].

Our standard protocol to identify primary aldosteronism (PA) and functional laterization:
Hypertensive patients were diagnosed with primary aldosteronism based on the following criteria [2-4] (Fig S1):

Confirmation
Fulfillment of the following three conditions confirmed a diagnosis of PA:
(1) autonomous excess aldosterone production evidenced by an aldosterone-renin ratio (ARR) > 35; (2) a TAIPAI score larger than 60% [5]; (3) seated post-saline loading PAC > 16 ng/dL, or PAC/PRA > 35 (ng/dL)/(ng/mL/h) shown in a post-captopril test [6]. (Abbreviations: PAC, plasma aldosterone concentration; PRA, plasma renin activity).

The probability of PA (TAIPAI score) was equal to:
$1 + e^{-\beta}$; where β = (PAC [ng/dl] × [0.063]) + PRA [ng/ml/h] × [−0.205]) + ([ARR × 0.001] + BMI [kg/m^2] × [0.067]) + (Male × [−0.738] + SK [mmol/l] × [−1.512]) + (eGFR [ml/min/1.73 m^2] × [0.017]) + ([propensity score] × [−0.539] + [1.851])

Lateralization
1. Unilateral primary aldosteronism (uPA) was identified on the basis on the following four criteria[7]:
   (a) Confirmed PA diagnosis;
   (b) Imaging evidence for a unilateral adrenal adenoma or hyperplasia;
   (c) Lateralization of aldosterone secretion with adrenal vein sampling (AVS) or during dexamethasone suppression NP-59 SPECT/CT[8] to the above-mentioned imagine-finding side.

2. Selectivity and lateralization indices of AVS
   The selectivity index (SI) is defined as the ratio of the sampled cortisol concentration of each adrenal vein to that of the peripheral vein. The lateralization index (LI) is defined as the ratio of the aldosterone/cortisol concentration on the dominant side to that on the contralateral side. Successful AVS is defined as an SI value ≥2.0 bilaterally. After confirming successful bilateral AVS, lateralization of the PA was determined by an LI value ≥2.0.[11]

Selectivity and lateralization indices of NP-59 SPECT/CT, here we summarize it as:

When the patients and/or the physician did not prefer or could not perform an AVS for PA lateralization, lateralization of aldosterone secretion was confirmed with a dexamethasone suppression 131I-6b-Iodomethyl-19-Norcholesterol (NP-59) SPECT/CT [8, 12] with the combination use of a 5-point visual scale (3 or 4 of 0~4 scale); , and semi-quantification of adrenal to liver ratio (ALR; cut-off value= 2.28) and lesion to contralateral ratio of bilateral adrenal glands (CON; cut-off value= 1.11) to lateralize the functional lesion to the side of the adrenal glands with the adenoma.

The total examination period for NP-59 scintigraphy is 8 days. To avoid the interruption of NP-59 uptake in adrenal glands, some anti-hypertensive medications should be held prior to NP-59 injection. Oral dexamethasone (8 mg daily, divided into two doses throughout the study) with a total dose of 64 mg is given to ensure maximal suppression of normal adrenal cortical uptake. One mL of diluted Lugol's solution daily is also given throughout the study to protect the thyroid from free 131I uptake; 37 MBq (1 mCi) NP-59 is injected slowly via venous route on the fourth day of the study.
Planar imaging with anterior and posterior views is routinely performed at 72 h after NP-59 injection. Abdominal SPECT/CT is performed at 96 h after NP-59 injection if no obvious lesion is recognized by 72 h imaging.
Mild laxatives can be used each night before NP-59 imaging to reduce intestinal background activity. Image interpretation is usually done by a five-point visual scale (VS) of SPECT/CT. A scale value of 0 points represents no significant uptake by the adrenal gland, 1 point represents faint uptake less than or equal to liver uptake, 2 points represents bilaterally symmetric uptake slightly greater than liver uptake, 3 points represents focal unilateral or

asymmetric uptake greater than liver uptake and 4 points represents intense unilateral or asymmetric uptake significantly greater than liver uptake. An adrenal lesion is considered an APA if VS is either 3 or 4.2 Semiquantification by drawing regions of interest (ROI) of adrenal glands and liver on the transaxial view of SPECT/CT provides better ability to differentiate APA from IAH. Semiquantification also provides a predictive value of clinical outcome after adrenalectomy[7].

Material and methods

The concentration of aldosterone was measured with a radioimmunoassay using commercial kits (Aldosterone Maia Kit; Adaltis Italia S.r.l., Bologna, Italy). The lowest detectable concentration of aldosterone was 1.0 ng/dL. The normal range of aldosterone is 7–35 ng/dL with the patient in the upright position. Plasma renin activity (PRA) was measured via the generation of angiotensin I in vitro, using a commercially available radioimmunoassay kit (Stillwater, MN, USA). The normal range of PRA is 2.63 ± 1.32 ng/mL/ h with the patient in the upright position. The mean (standard deviation [SD]) intra- and interassay coefficients of variation for the PRA assay were 1.9 (5.0%) and 4.5 (5.2%), respectively.

Targeted Next-Generation Sequencing

1. NGS was made in-house. Primers were ordered from Integrated DNA Technologies IDT, Inc.
2. Tools used to design the panel:
   i. UCSC Genome Browser on Human Feb. 2009 (GRCh37/hg19) Assembly: https://genome.ucsc.edu/cgi-bin/hgTracks?db=hg19&lastVirtModeType=default&lastVirtModeExtraState=&virtModeType=default&virtMode=0&nonVirtPosition=&position=chrX%3A15578261%2D15621068&hgsid=1144608959_9JwbUaZAIABu5TyYWIrW03hc6Hzh
   ii. Primer-BLAST: https://www.ncbi.nlm.nih.gov/tools/primer-blast/
3. Primers per gene:
   KCNJ5: 7; ATP1A1: 27; ATP2B3: 31; CACNA1D: 55; CACNA1H: 47; CLCN2: 24; CTNNB1: 23 (Total primer pairs: 214)
4. Total size of the target region: 55,909bp
5. MiniSeq was used with High Output Reagent 2x150 kit. Read length was

set as: 151+10+151. 96 samples were pooled in one run without PhiX (balanced library composed of more than 200 amplicon).

6. First run: 96 sample; cluster density: 337±2; PF: 75.99±0.61; Q30: 86.66;
7. Second run: 96 sample; cluster density: 162±2; PF: 94.72±0.24; Q30: 95.24

Table S1. Primers used for Sanger sequencing

***KCNJ5* (NM_000890.5)**			**Detectable mutations**	**Base pair**
KCNJ5 GC*[13]*	Forward	CTTCATTTGGTGGCTCATTGC	p.Thr148Ile p.Thr149Ser p.Thr148_Thr149ins Arg p.Thr149dup p.Gly151Glu p.Gly151Arg p.Tyr152Cys p.Phe154Gys p.Ile157del p.Ile157Ser p.Thr158Ala p.Leu168Arg	410
	Reverse	GGACTTGATGAGCTTGGC		
KCNJ5 G2*[13]*	Forward	CTTTCCTGTTCTCCATTGAGACC	p.Glu246Gly	544
	Reverse	CTGAGGAGGACAAAGCGCC		

***ATP2B3* (NM_001001344.2)**			**Detectable mutations**	**Base pair**
ATP2B3-Exon 8	Forward	CCTGGGCTGTTTATCCTGAA	p.Val424_Leu425del p.Leu425_Val426del p.Val426_Val427del	416
	Reverse	CCCCAGTTTCCGAGTCTGTA		

***CTNNB1* (NM_001904.4)**			**Detectable mutations**	**Base pair**
CTNNB1-Exon*[14]*	Forward	CATTCTGCTTTTCTTGGCTGTC	p.Ser33Cys p.Gly34Arg p.Ser45Phe p.Ser45Pro p.Ser45Cys	483
	Reverse	GCTATTACTCTCTTTTCTTCCC		

***CLCN2* (NM_004366.6)**			**Detectable mutations**	**Base pair**
CLCN2 -Exon 2[15]	Forward	GTGGG AACTG TGCGT TCAAG	p.Gly24Asp p.Met22Lys p.Tyr26Asn	360
	Reverse	AGCAG CTCTA ATGGC CTCTG		
CLCN2-Exon 5[16]	Forward	GGACC CCTGA AATGG GTGCA TCG	p.Arg172Gln	273
	Reverse	TGAGT CGGGA GGGGG CCCGC CCTG		

***ATP1A1* (NM_001160233.2)**			**Detectable mutations**	**Base pair**
ATP1A1-Exon 4	Forward	TTCCTTGGGCCTATTGTTTG	p.Gly99 Arg p.Leu104Arg p.Phe100_Leu104del p.Met102_Leu103del p.Met102_Ile106del p.leu103_Leu104del	487
	Reverse	GTGGGAGACA AAGACGGAGA		
ATP1A1-Exon 8	Forward	CGTGGCTTCCTTCAGGTTAG	p.Val332Gly	468
	Reverse	CGTGATGTGGCTCTCAAGAA		

Table S2. The definition of clinical and biochemical outcome according to the PASO consensus [17]

Outcome measure	Clinical outcome definition	Biochemical outcome definition
Complete success (remission)	Normal BP without the aid of antihypertensive medication	Correction of hypokalemia and normalization of the aldosterone-to-renin ratio
Partial success (improvement)	The same BP with less antihypertensive medication ***or*** A reduction in BP with either the same amount or less antihypertensive medication	Correction of hypokalemia and a raised aldosterone-to-renin ratio with one or both of the following (compared with pre-surgery): ≥50% decrease in baseline plasma aldosterone concentration; or abnormal but improved post-surgery confirmatory test result.
No (absence of) success (persistence)	Unchanged or increased BP levels with either the same amount or an increase in antihypertensive medication	Persistent hypokalemia or persistent raised aldosterone-to-renin ratio, or both, with failure to suppress aldosterone secretion with a post-surgery confirmatory test.

Table S3. Clinical characteristics of unilateral primary aldosteronism patients with respect to [NGS + Sanger]-identified mutations

	All	Mutation carrier	Mutation non-carrier	p value (mutation carrier vs. non-carrier)
Number	240	186	54	
Female(%)	134(55.8%)	105(56.5%)	29(53.7%)	0.876
Age (years)	49.7(10.9)	48.5(11.0)	54.9(10.7)	0.001
BMI (kg/m^2)	25.4(4.2)	25.2(4.2)	26.5(4.2)	0.08
sBP (mmHg)	153.5(22.8)	153.2(23.4)	154.6(20.7)	0.689
dBP (mmHg)	91.9(15.4)	91.9(16.0)	91.8(13.3)	0.833
PRA (ng/ml per min) †		0.79(3.38)	0.64(1.06)	0.741
Plasma aldosterone (ng/dl) †	62.4(47.6)	65.8(49.8)	50.8(37.2)	0.045
Log ARR†	2.41(0.80)	2.44(0.80)	2.26(0.79)	0.241
Potassium (mmol/L) †	3.4(0.7)	3.3(0.7)	3.5(0.6)	<0.0001
Serum creatinine (mg/dl)	0.91(0.37)	0.90(0.37)	0.95(0.38)	0.480
Tumor size (cm)	1.83(1.23)	1.76(0.63)	2.02(2.43)	0.363
Clinical success¶ (%)				<0.0001
Complete	148(61.7%)	130(69.9%)	18(33.3%)	
Absent	26(10.8%)	13(7.0%)	13(24.1%)	
Partial	66(27.5%)	43(23.1%)	23(42.6%)	
Biochemical success¶ (%)				0.460
Complete	206(85.8%)	163(87.6%)	43(79.6%)	
Absent	22(9.2%)	15(8.1%)	7(13%)	
Partial	12(5%)	8(4.3%)	4(7.4%)	

Abbreviations: ARR, aldosterone-renin ratio; BMI, body mass index; cNGS, customized targeted next-generation sequencing; dBP, diastolic blood pressure; PRA, plasma renin activity; PWV, pulse wave velocity; sBP, systolic

blood pressure; *Data are expressed as mean (standard deviation) unless otherwise indicated.

†Obtained after hold drug that will interfere the renin-angiotensin system.

¶ Definition of postoperative outcome: Evaluation was performed at 12 months postoperatively. Clinical success was defined as resolution of hypertension and no need for antihypertensive medications. **Complete biochemistry success** was defined as aldosterone-to-plasma renin activity ratio <38 and serum potassium ≥3.5.

Table S4. Likelihood Ratio Tests of variables related to complete clinical success by multinomial logistic regression analysis§

	Model Fitting Criteria			Likelihood Ratio Tests	
	AIC of Reduced Model	BIC of Reduced Model	-2 Log Likelihood of Reduced Model	Chi-Square	Sig.
Age(yr)	397.961	473.599	353.961	10.872	.004
BMI (kg/m^2)	392.149	467.787	348.149	5.060	.080
SBP(mmHg)	390.104	465.742	346.104	3.015	.221
DBP(mmHg)	390.549	466.186	346.549	3.460	.177
Aldosterone(ng/dL) †	388.478	464.116	344.478	1.389	.499
PRA(ng/mL/hr) †	389.666	465.304	345.666	2.577	.276
Potassium(mEq/L) †	395.096	470.734	351.096	8.007	.018
Cr (mg/dL)	388.598	464.236	344.598	1.509	.470
Tumor size (cm)¶	389.196	464.833	345.196	2.107	.349
[NGS+Sanger]-*identified* mutation (yes)	398.312	473.950	354.312	11.223	.004
Sex (Female)	387.789	463.427	343.789	.700	.705

Abbreviations: BMI, body mass index; Cr, Serum creatinine; dBP, diastolic blood pressure; PRA, plasma renin activity; sBP, systolic blood pressure;

§The chi-square statistic is the difference in -2 log-likelihoods between the final model and a reduced model. The reduced model is formed by omitting an effect from the final model. The null hypothesis states all parameters of that effect are 0.

¶ Tumor size was measured using computed tomography or magnetic resonance imaging.

†Obtained after hold drug that will interfere the renin-angiotensin system.

Table S5. Likelihood Ratio Tests of cNGS-identified mutation related to complete clinical success by multinomial logistic regression analysis with models adjusted for different clinical co-variables

		Model I	Model II	Model III	Model IV	Model V
Model Fitting Criteria	AIC of Reduced Model	163.106	168.688	171.898	170.488	172.646
	BIC of Reduced Model	186.281	201.133	208.978	216.837	223.631
	-2 Log Likelihood of Reduced Model	143.106	140.688	139.898	130.488	128.646
Likelihood Ratio Tests of cNGS-identified mutation (yes)	Chi-Square	8.931	10.257	10.582	9.108	8.926
	Sig.	0.012	0.006	0.005	0.011	0.012

Model I: adjusted by sex, age, BMI, and tumor size

Model II: adjusted by sex, age, BMI, tumor size, PAC, and PRA

Model III: adjusted by sex, age, BMI, tumor size, PAC, PRA, and serum potassium

Model IV: adjusted by sex, age, BMI, tumor size, SBP, DBP, PAC, PRA, and serum potassium

Model V: adjusted by sex, age, BMI, tumor size, SBP, DBP, PAC, PRA, serum potassium, and serum Cr

Table S6. Likelihood Ratio Tests of Sanger sequencing-identified mutation related to complete clinical success by multinomial logistic regression analysis§

	Model Fitting Criteria			Likelihood Ratio Tests	
	AIC of Reduced Model	BIC of Reduced Model	-2 Log Likelihood of Reduced Model	Chi-Square	Sig.
Age(yr)	369.404	443.455	325.404	13.955	.001
BMI (kg/m^2)	361.911	435.963	317.911	6.463	.039
SBP(mmHg)	358.197	432.248	314.197	2.749	.253
DBP(mmHg)	360.159	434.210	316.159	4.711	.095
Aldosterone(ng/dL) †	356.149	430.201	312.149	0.701	.704
PRA(ng/mL/hr) †	356.491	430.543	312.491	1.043	.594
Potassium(mEq/L) †	362.437	436.489	318.437	6.989	.030
Cr (mg/dL)	358.646	432.697	314.646	3.197	.202
Tumor size (cm)¶	357.499	431.551	313.499	2.051	.359
Sanger sequencing *-identified* mutation (vs. mutation negative)	363.867	437.919	319.867	8.419	.015
Sex (Female)	356.393	430.444	312.393	0.944	.624

Abbreviations: BMI, body mass index; Cr, Serum creatinine; dBP, diastolic blood pressure; PRA, plasma renin activity; sBP, systolic blood pressure;

§The chi-square statistic is the difference in -2 log-likelihoods between the final model and a reduced model. The reduced model is formed by omitting an

effect from the final model. The null hypothesis states all parameters of that effect are 0.

¶ Tumor size was measured using computed tomography or magnetic resonance imaging.

†Obtained after hold drug that will interfere the renin-angiotensin system.

Table S7. Likelihood Ratio Tests of cNGS-identified mutation related to complete clinical success by multinomial logistic regression analysis among 51 uPA with CYP11B2-expressing adrenocortical tumors§

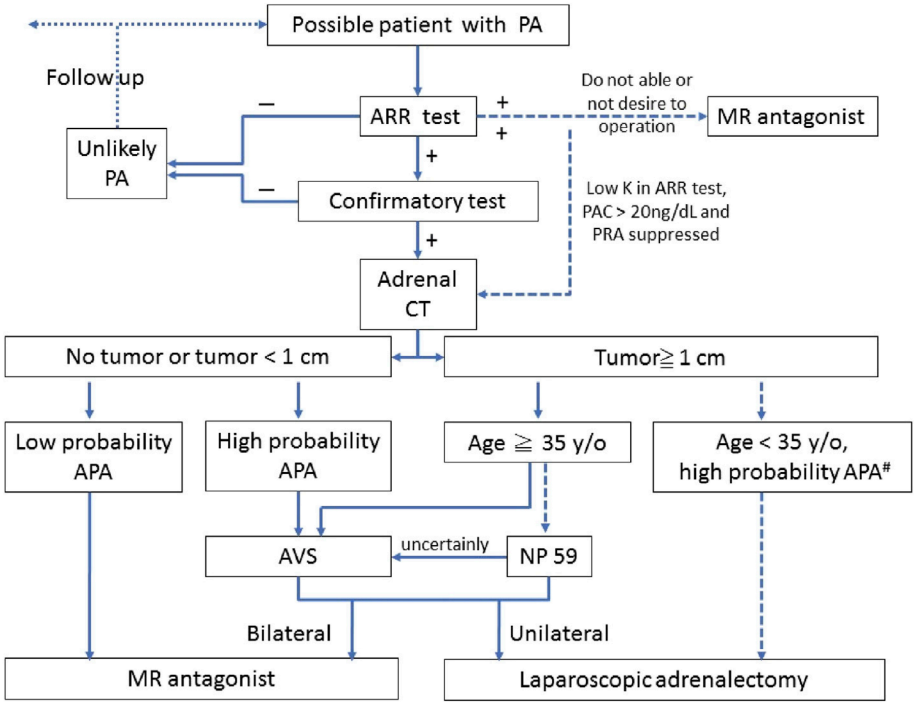
	Model Fitting Criteria			**Likelihood Ratio Tests**	
	AIC of Reduced Model	BIC of Reduced Model	-2 Log Likelihood of Reduced Model	Chi-Square	Sig.
Age(yr)	84.747	119.584	40.747	2.284	.319
BMI (kg/m^2)	88.083	122.920	44.083	5.620	.060
SBP(mmHg)	82.784	117.621	38.784	.321	.852
DBP(mmHg)	83.987	118.824	39.987	1.524	.467
Aldosterone(ng/dL) †	87.131	121.968	43.131	4.668	.097
PRA(ng/mL/hr) †	86.521	121.359	42.521	4.058	.131
Potassium(mEq/L) †	84.511	119.348	40.511	2.048	.359
Cr (mg/dL)	84.878	119.716	40.878	2.415	.299
Tumor size (cm)¶	82.590	117.427	38.590	.127	.939
cNGS-*identified* mutation (yes)	94.494	129.331	50.494	12.031	.002
Sex (Female)	87.092	121.929	43.092	4.629	.099

Abbreviations: BMI, body mass index; Cr, Serum creatinine; dBP, diastolic blood pressure; PRA, plasma renin activity; sBP, systolic blood pressure;

§The chi-square statistic is the difference in -2 log-likelihoods between the final model and a reduced model. The reduced model is formed by omitting an effect from the final model. The null hypothesis states all parameters of that effect are 0.

¶ Tumor size was measured using computed tomography or magnetic resonance imaging.
†Obtained after hold drug that will interfere the renin-angiotensin system.

Figure S1. The diagnosis and treatment protocol of TAIPAI. [3, 6, 10].

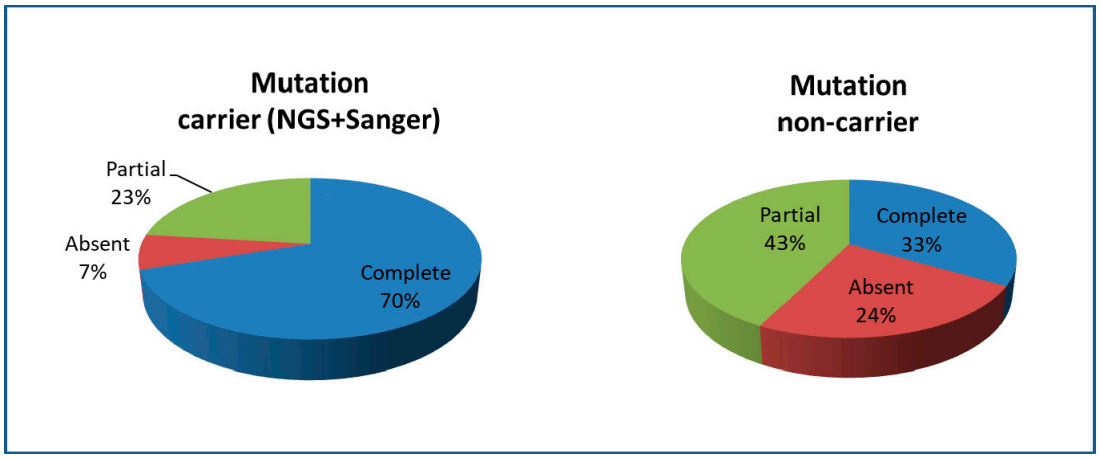


Patients < 35 years with adrenal lesion S 1 cm can also receive AVS if clinically indicated.

Abbreviations: APA, aldosterone-producing adenomas; ARR, aldosterone-to-renin ratio; AVS, adrenal venous sampling; CT, computed tomography; NP-59- SPECT, I-131-6-beta-iodomethyl-19-norcholesterol single-photon emission

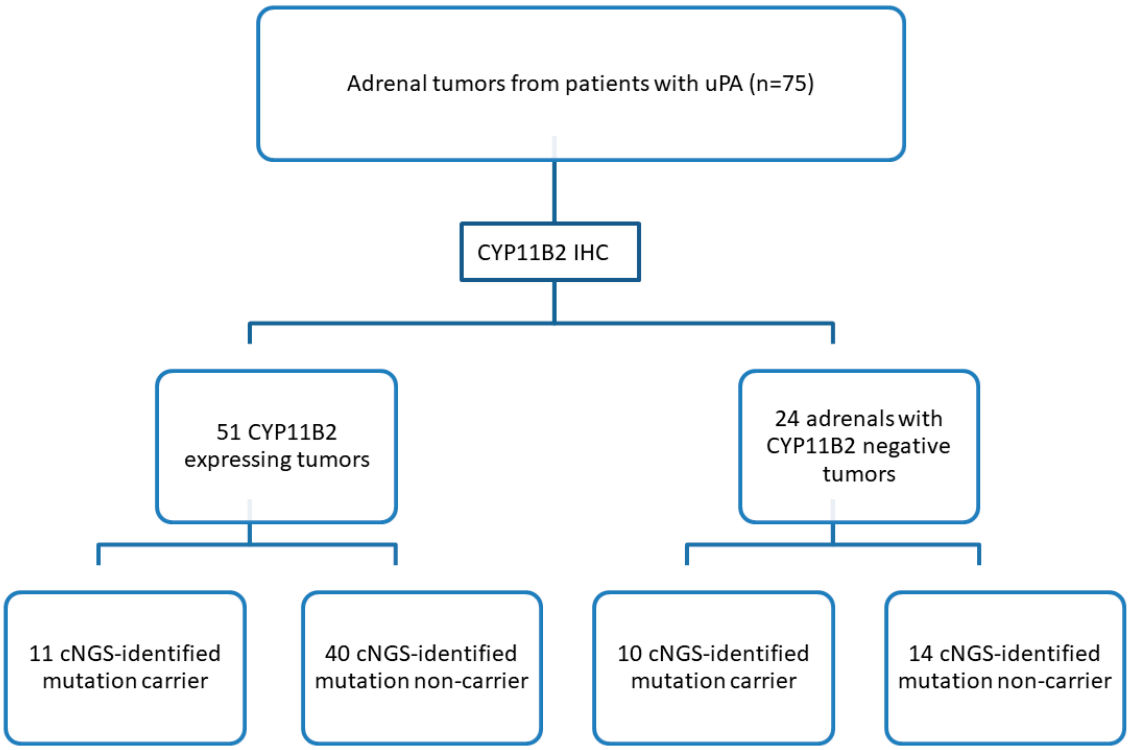
computed tomography

Figure S2. Clinical outcome for 240 patients with unilateral primary aldosteronism who underwent adrenalectomy with respect to detected mutations via customized targeted next-generation sequencing + Sanger sequencing.



¶ Definition of postoperative outcome: Evaluation was performed at 12 months postoperatively. Clinical success was defined as resolution of hypertension and no need for antihypertensive medications.

Figure S3. Characteristics of tumoral tissues of unilateral primary aldosteronism based on the results of CYP11B2 immunohistochemistry



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