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C–H Bond Functionalization via [1,5]-Hydride Shift/Cyclization Sequence: Approach to Spiroindolenines

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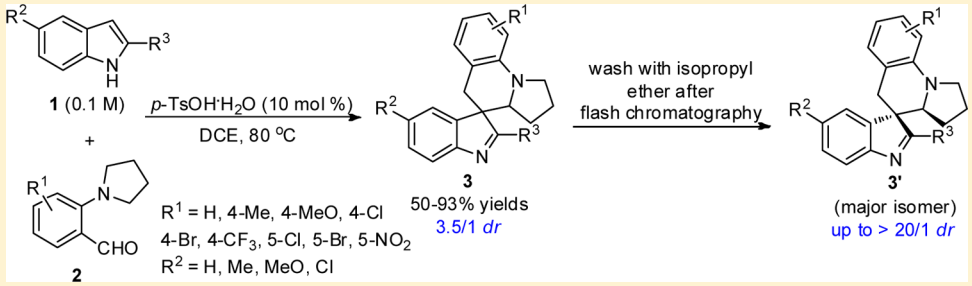
Supporting Information



ABSTRACT: A concise synthesis of spiroindolenines from 2-substituted (Me, Et) indoles and 2-(pyrrolidin-1-yl)benzaldehydes has been developed via a [1,5]-hydride shift/cyclization sequence. This method features a wide substrate scope and an operationally simple procedure, affording the spiroindolenines in good to excellent yields and moderate diastereoselectivity (3.5/1 dr). When the inseparable mixture of spiroindolenine isomers were washed with isopropyl ether after flash chromatography, the major isomers could be obtained in up to >20/1 dr.

INTRODUCTION

Polycyclic spiroindolines and spiroindolenines are widespread structures existing in many alkaloid natural products as well as some pharmaceutically active compounds.[1,2] Representative spirocyclic compounds are showed in Figure 1. The importance of this structural motif has motivated the development of elegant synthetic methodologies for construction of these complex building blocks.[3] The direct route to spiroindolenine substructure would go through dearomatization of indole derivatives involving a cascade sequence.[4] Recently, the You and Rawal groups reported transition-metal-catalyzed allylic dearomatization reactions of indole derivatives to provide spiroindolenines.[5−7] After that, the You group also applied Pd-catalyzed dearomative arylation of indoles to afford spiroindolenine derivatives.[8] In 2013, the Movassaghi group synthesized spirocyclic indolines by means of the Bischler−Napieralski reaction of 2H-*N*-acyl tryptamines via persistent spiroindolenium intermediates.[9] More recently, the Zhou group disclosed the reaction of ylides with vinylogous imine intermediates to furnish the spirocyclopropane compounds.[10]

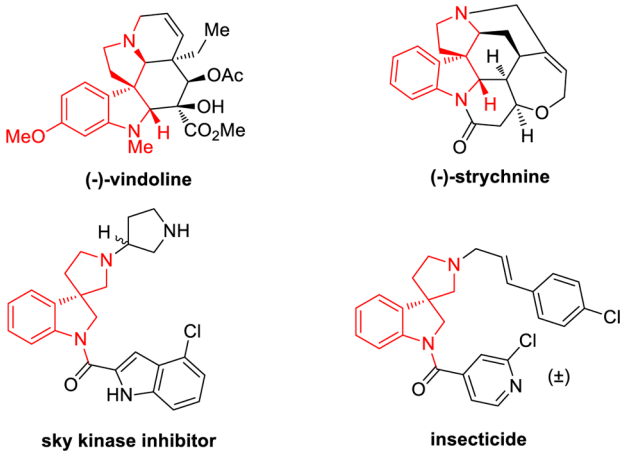


Figure 1. Representative molecules containing polycyclic spiroindoline motifs.

The redox-neutral process as a novel approach to C–H functionalization has received considerable attention in modern organic chemistry due to its atom- and step-economy. Until now, different types of unsaturated bonds, such as electron-poor alkenes, aldehydes, ketones, imines, alkynes, and allenes, have been employed as hydride acceptors.[11,12] In 2011, Seidel and co-workers reported that aminobenzaldehydes reacted with indoles involved a 1,5-hydride shift, resulting in the formation of seven-membered polycyclic azepinoindoles (path a, Scheme 1).[13] We are interested in developing a redox-neutral cascade reaction for the rapid construction of spirocyclic molecules. Herein, we disclose a new method for synthesis of spiroindolenines via a [1,5]-hydride shift/cyclization sequence involving the Brønsted acid-catalyzed reaction of 2-substituted

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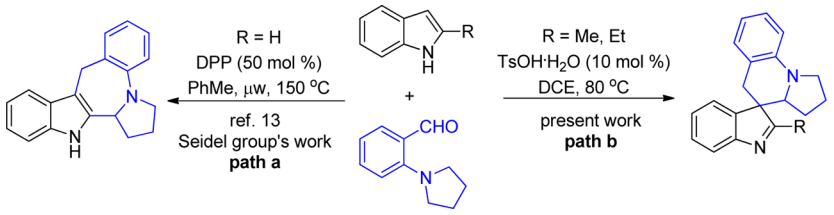
Scheme 1. Strategies for Aminobenzaldehydes Reacted with Indoles Involving a 1,5-Hydride Shift Reaction

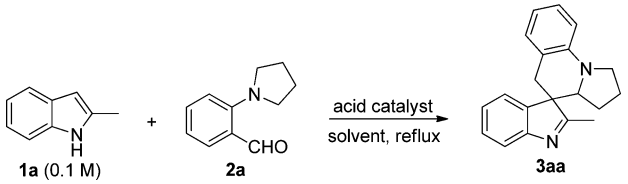


indoles with 2-(pyrrolidin-1-yl)benzaldehydes (path b, Scheme 1).

RESULTS

2-Methylindole **1a** and 2-(pyrrolidin-1-yl)benzaldehyde **2a** were chosen as model substrates for the initial studies. Different acid catalysts were examined, and the results are summarized in Table 1. Different Lewis acids could be tolerated in the reaction, but the products were obtained in only moderate yields (entries 1−5, Table 1). When weak Brønsted acids (up to 200 mol %) were used in the reaction, the yields could not be improved (entries 6−9, Table 1). However, when *p*-TsOH·H_2O was employed as the catalyst, the desired product could be obtained in 64% yield (entry 12, Table 1). With a variety of acid catalysts screened, the diastereoselectivity of the reaction was almost preserved at 3.5/1 dr, leading to an inseparable mixture of diastereoisomers. We proposed that the diastereoselectivity of compound **3aa** might be retained in equilibrium under acid conditions. We found that when the single isomer of compound **3aa** (>20/1 dr) was stirred under acid conditions, the diastereoselectivity could convert to 3.5/1. Next, when using *p*-TsOH·H_2O as the acid catalyst, various solvents were evaluated (Table 1). Toluene, DCE, THF, and CH_3CN could all be tolerated (entries 12−15, Table 1). Finally, DCE was determined as the optimal solvent, affording the desired product in 87% yield and 3.5/1 dr (entry 13, Table 1).

Table 1. Screening of Acid Catalysts and Solvents[a]

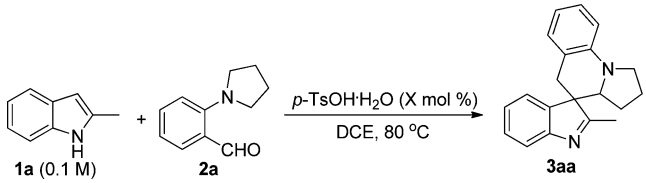


entry	catalyst (mol %)	solvent	time (h)	yield (%)	dr[b]
1	$FeCl_3$ (10)	toluene	24	29	3.5/1
2	$AlCl_3$ (10)	toluene	24	48	3.5/1
3	$ZnCl_2$ (10)	toluene	24	43	3.5/1
4	$Cu(OTf)_2$ (10)	toluene	3	29	3.5/1
5	$Sc(OTf)_3$ (10)	toluene	3	48	3.5/1
6	CH_3COOH (200)	toluene	24	16	3.5/1
7	PhCOOH (100)	toluene	24	40	3.5/1
8	H-mont (50)	toluene	24	34	3.5/1
9	CF_3COOH (10)	toluene	3	39	3.5/1
10	CF_3SO_3H (10)	toluene	3	50	3.5/1
11	CSA (10)	toluene	3	58	3.5/1
12	*p*-TsOH·H_2O (10)	toluene	3	64	3.5/1
13[c]	*p*-TsOH·H_2O (10)	DCE	8	87	3.5/1
14	*p*-TsOH·H_2O (10)	THF	12	74	3.5/1
15	*p*-TsOH·H_2O (10)	MeCN	10	63	3.5/1

[a]Reaction conditions: **1a** (0.364 mmol, 0.1 M), **2a** (0.40 mmol), acid catalyst in solvent, reflux. [b]Determined by ^1H NMR of crude product. [c]Reacted at 80 °C.

Further studies on the effect of the catalyst loading and reaction temperature were carried out. The results are shown in Table 2. We found that the reaction could proceed well in the presence of 20 or 10 mol % *p*-TsOH·H_2O (entries 1, 2, Table 2). When the catalyst loading was reduced to 5 mol %, the yield was decreased to 73% (entry 3, Table 2). Notably, the product could also be obtained in 73% yield even if the loading of *p*-TsOH·H_2O was decreased to only 1 mol % (entry 5, Table 2). When the reaction temperature lowered to r.t., the product was obtained in 69% yield with the same diastereoselectivity (entry 7, Table 2). Finally, we determined the optimized reaction conditions: 10 mol % *p*-TsOH·H_2O as the catalyst, DCE as the solvent, and 80 °C as the reaction temperature.

Table 2. Screening of Catalyst Loading and Reaction Temperature[a]



entry	X	*T* (°C)	time (h)	yield (%)	dr[b]
1	20	80	2	87	3.5/1
2	10	80	8	87	3.5/1
3	5	80	12	73	3.5/1
4	2.5	80	24	73	3.5/1
5	1	80	24	73	3.5/1
6	10	50	12	71	3.5/1
7	10	r.t.	12	69	3.5/1

[a]Reaction conditions: **1a** (0.364 mmol, 0.1 M), **2a** (0.40 mmol), *p*-TsOH·H_2O in DCE. [b]Determined by ^1H NMR of crude product.

With the optimized reaction conditions in hand, various substituted 2-(pyrrolidin-1-yl)benzaldehydes **2** were reacted with 2-methylindole **1a** to examine the substrate scope (Scheme 2). 2-(Pyrrolidin-1-yl)benzaldehydes with both electron-donating and -withdrawing groups could be tolerated in the reaction, affording desired products **3** in the same diastereoselectivity (3.5/1 dr). Interestingly, when an inseparable mixture of diastereoisomers was washed with isopropyl ether after flash chromatography, the major isomers **3ab′**−**3ai′** could be obtained in up to >20/1 dr. We thought that the diastereoselectivity was improved because of the different solubilities of the two isomers in the isopropyl ether. The relative configuration of **3ac′** was confirmed by X-ray crystallography.[14] While the desired products (e.g., **3ab′**, **3ac′**) were obtained in only moderate yields (50−60%) from 2-(pyrrolidin-1-yl)benzaldehydes substituted with electron-donating groups (e.g., 4-Me, 4-MeO), reaction of 2-

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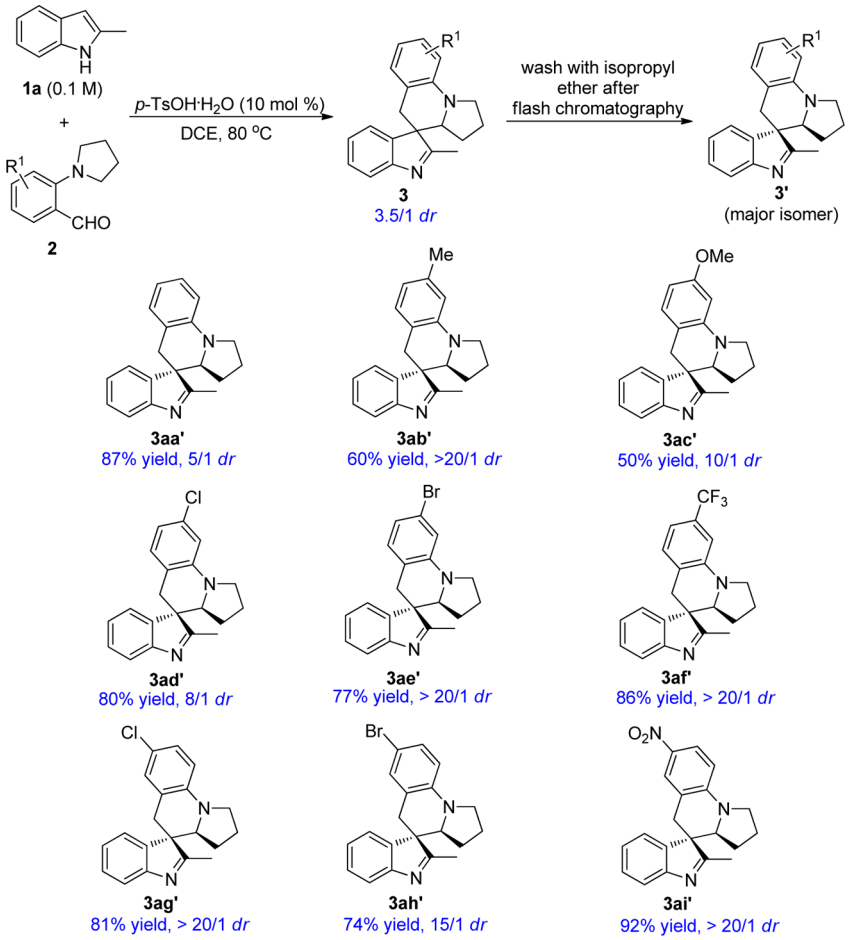
Scheme 2. Scope of the 2-(Pyrrolidin-1-yl)benzaldehyde Component[a]



[a]Reaction conditions: **1a** (0.364 mmol, 0.1 M), **2** (0.40 mmol), *p*-TsOH·H_2O (10 mol %) in DCE, reflux. dr was determined by ^{1}H NMR. The yields of the products were determined after flash chromatography.

(pyrrolidin-1-yl)benzaldehydes substituted with electron-withdrawing groups afforded the desired products (e.g., **3ad**′, **3ae**′, **3af**′, **3ag**′, **3ah**′, **3ai**′) in good to excellent yields (74−92%).

To examine the scope of the 2-substituted indole component, different substituted 2-methylindoles (5-Me, 5-MeO, and 5-Cl) were allowed to react with 2-(pyrrolidin-1-yl)benzaldehydes **2**, respectively. As summarized in Scheme 3, while reaction of 5-methoxy-2-methylindole **1c** with various 2-(pyrrolidin-1-yl)benzaldehydes afforded the desired products (**3ca**′, **3cg**′, **3ci**′) in high yields (83−93%), reaction of 5-chloro-2-methylindole **1d** with 2-(pyrrolidin-1-yl)benzaldehydes substituted by electron-donating groups resulted in low yields of products (e.g., **3db**′), indicating that the reaction preferred 2-methylindoles with electron-donating groups. Notably, the reaction of 2-(pyrrolidin-1-yl)benzaldehyde **2i** (5-NO_2) with a variety of 2-methylindoles afforded the corresponding products (**3bi**′, **3ci**′, **3di**′) in high yields (90−91%), no matter the pattern of substitution on 2-methylindoles. To further broaden the scope of this reaction, when 2-ethylindole was employed in the reaction, the desired product could be obtained in 64% yield. Nevertheless, in any case, the diastereoselectivity remained at the ratio of 3.5/1. As above, when the diastereoisomer mixtures were washed with isopropyl ether after flash chromatography, the major isomers could be readily obtained in 5/1 to > 20/1 dr (Scheme 3).

Next, we investigated the reaction of 2-methylindole **1a** with 2-(piperidin-1-yl)benzaldehyde **2j** and 2-morpholinobenzaldehyde **2k**. The desired spiroindolenines could not be detected, while the reaction conducted at room temperature only led to the formation of the bis(indolyl)methane **4a** and **4b** in 89% and 96% yields, respectively (Scheme 4).

A plausible mechanism for this acid-catalyzed [1,5]-hydride shift/cyclization reaction is depicted in Scheme 5. First of all, 2-(pyrrolidin-1-yl)benzaldehyde **2a** reacts with 2-methylindole **1a** to form iminium **6** via dehydration. Acid catalyst facilitates [1,5]-hydride shift to form **7**, followed by ring closure, giving the diastereoisomer mixtures containing **3aa**′ and **3aa**″. On the basis of the observation that the conversion between **3aa**′ and **3aa**″ readily occurs under acid conditions, we proposed that the last step of the reaction to form **3aa**′ and **3aa**″ is reversible to achieve an equilibrium, thus leading to a constant diastereoselectivity at 3.5/1.

We also attempted to develop a catalytic asymmetric version of this methodology for access to enantioenriched spiroindolenines. After different chiral BINOL-derived phosphoric acids were screened,[15,16] the product was only obtained in 77% yield with 3.5/1 dr and 2% ee (**3aa**′) (Scheme 6).

In conclusion, we have developed a new strategy for the synthesis of spiroindolenine derivatives via a [1,5]-hydride shift/cyclization sequence using *p*-TsOH·H_2O as the catalyst. The spiroindolenine derivatives were obtained in good to

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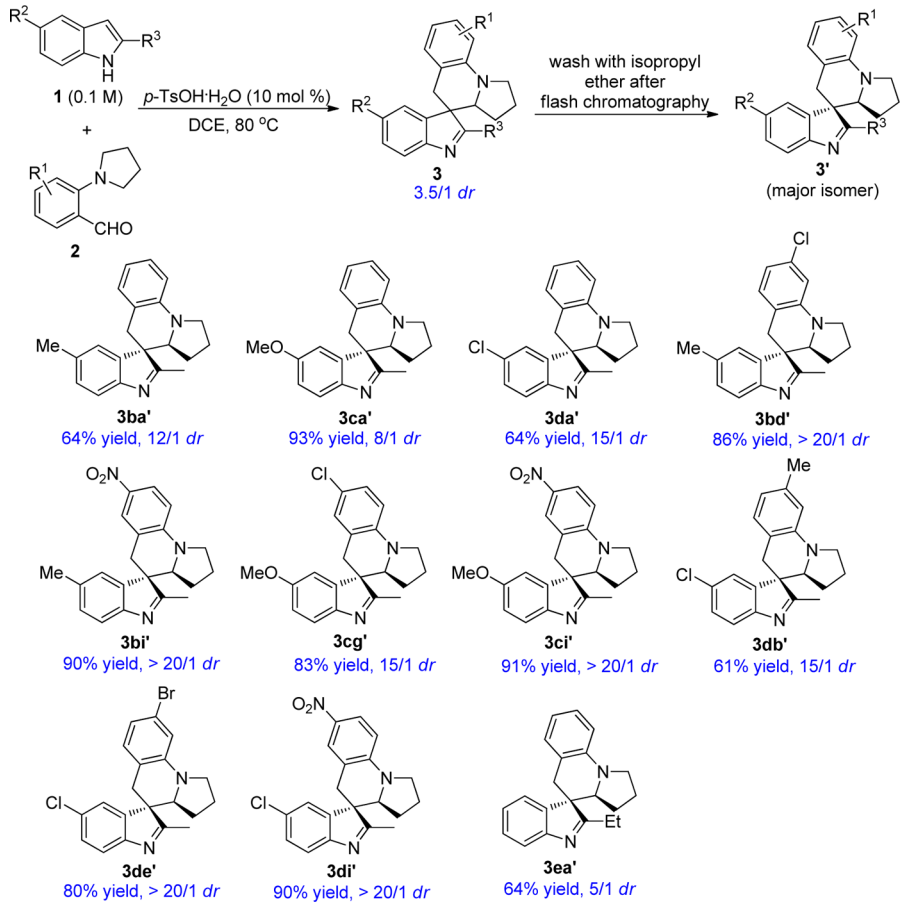
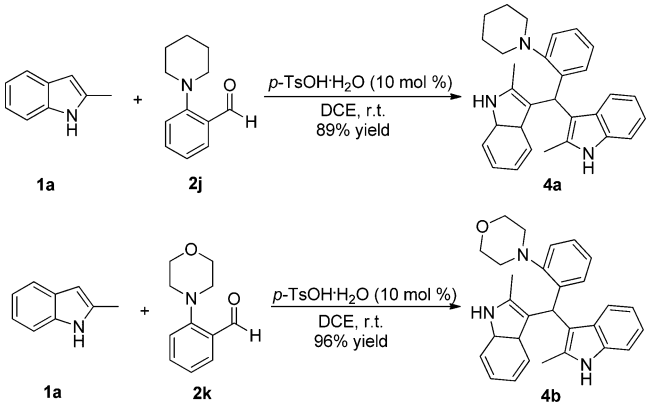
Scheme 3. Scope of the 2-Substituted Indole Component[a]

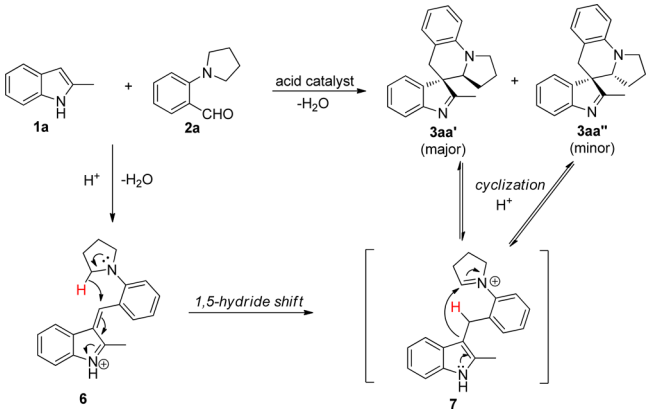


[a]Reaction conditions: **1** (0.364 mmol, 0.1 M), **2** (0.40 mmol), *p*-TsOH·H_2O (10 mol %) in DCE, reflux. dr was determined by ^{1}H NMR. The yields of the products were determined after flash chromatography.

Scheme 4. Reaction of 2-Methylindole 1a with 2-(Piperidin-1-yl)benzaldehyde 2j and 2-Morpholinobenzaldehyde 2k



Scheme 5. Proposed Mechanism of the [1,5]-Hydride Shift/Cyclization Reaction



excellent yields with a constant diastereoselectivity at 3.5/1. The major diastereoisomer product could be readily obtained with up to >20/1 dr by simple washing with isopropyl ether after flash chromatography. A preliminary experiment for the catalytic enantioselective variant of this methodology with a chiral BINOL-derived phosphoric acid as the catalyst could deliver the corresponding product in 77% yield with 3.5/1 dr and 2% ee.

EXPERIMENT SECTION

General Information. ^{1}H NMR and ^{13}C NMR (300 and 75 MHz, respectively) spectra were recorded in $CDCl_3$ and DMSO-d_6. ^{1}H NMR chemical shifts are reported in ppm relative to tetramethylsilane (TMS) with the solvent resonance employed as the internal standard ($CDCl_3$ at 7.26 ppm, DMSO-d_6 at 2.50 ppm). Data are reported as follows: chemical shift, multiplicity (s = singlet, br s = broad singlet, d = doublet, t = triplet, q = quartet, m = multiplet), coupling constants (Hz), and integration. ^{13}C NMR chemical shifts are reported in ppm

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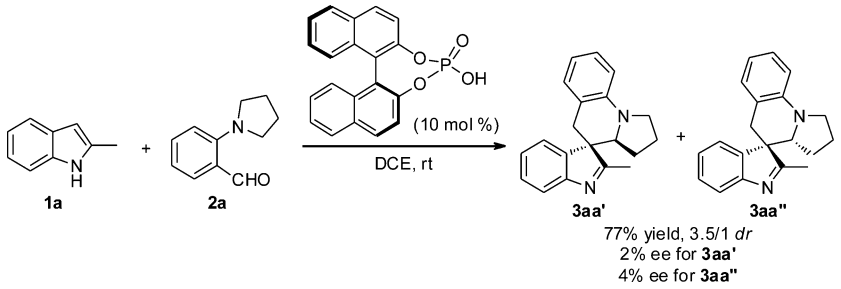
Scheme 6. Catalytic Asymmetric Version of This Methodology



from tetramethylsilane (TMS) with the solvent resonance as the internal standard ($CDCl_3$ at 77.20 ppm, DMSO-d_6 at 39.51 ppm). The substrate aminobenzaldehyde derivatives **2** were synthesized according the literature report.[13]

General Procedure for the Intramolecular Redox Reaction Catalyzed by *p*-TsOH·H_2O. To a solution of **1a−e** (0.30−0.364 mmol, 0.1 M) and **2** (0.33−0.40 mmol) in $ClCH_2CH_2Cl$ was added *p*-TsOH·H_2O (10 mol %), and then the reaction mixture was stirred at 80 °C until complete consumption as monitored by TLC. The solvents were removed under reduced pressure, and flash chromatography was used to give the desired product **3** (two isomers). The isomers were washed with $^iPr_2O$, and the major isomer could be obtained (diastereoselectivity shown in parentheses).

2-Methyl-2′,3′,3a′,5′-tetrahydro-1′*H*-spiro[indole-3,4′-pyrrolo[1,2-*a*]quinoline] (3aa′). Eluent: petroleum ether/ethyl acetate (10/1). Pale yellow solid, 90 mg, 87% yield, 3.5/1 dr (5/1 dr), mp 108−109 °C. ^{1}H NMR (300 MHz, DMSO-d_6) δ 7.45 (d, J = 7.5 Hz, 1H), 7.23 (t, J = 7.5 Hz, 1H), 7.16 (t, J = 7.6 Hz, 1H), 6.95−6.87 (m, 2H), 6.60−6.55 (m, 2H), 6.38 (d, J = 7.2 Hz, 1H), 3.99 (dd, J = 9.6, 6.0 Hz, 1H), 3.51 (m, 1H), 3.44 (AB, J = 15.6 Hz, 1H), 3.08 (appq, J = 8.7 Hz, 1H), 2.28 (AB, J = 15.3 Hz, 1H), 2.27 (s, 3H), 1.84−1.80 (m, 2H), 1.63−1.57 (m, 1H), 0.45−0.30 (m, 1H). ^{13}C{1H} NMR (75 MHz, DMSO-d_6) δ 184.3, 155.0, 143.8, 139.1, 129.1, 127.8, 127.6, 124.5, 123.2, 119.2, 117.8, 115.2, 110.0, 60.5, 55.7, 47.1, 35.1, 26.2, 22.8, 15.9. HRMS (ESI-TOF): Exact mass calcd for $C_{20}H_{20}N_2Na$ [M + Na]$^+$: 311.1524, found 311.1530.

2,8′-Dimethyl-2′,3′,3a′,5′-tetrahydro-1′*H*-spiro[indole-3,4′-pyrrolo[1,2-*a*]quinoline] (3ab′). Eluent: petroleum ether/ethyl acetate (10/1). White solid, 66 mg, 60% yield, 3.5/1 dr (>20/1 dr), mp 123−125 °C. ^{1}H NMR (300 MHz, DMSO-d_6) δ 7.44 (d, J = 7.1 Hz, 1H), 7.22 (t, J = 7.5 Hz, 1H), 6.91 (t, J = 7.2 Hz, 1H), 6.82 (d, J = 7.2 Hz, 1H), 6.41−6.38 (m, 3H), 3.96 (dd, J = 9.0, 6.0 Hz, 1H), 3.47 (t, J = 8.7 Hz, 1H), 3.40 (AB, J = 16.2 Hz, 1H), 3.10 (dd, J = 16.8, 8.7 Hz, 1H), 2.28 (s, 3H), 2.26 (s, 3H), 2.23 (AB, J = 15.9 Hz, 1H), 1.87−1.69 (m, 2H), 1.65−1.56 (m, 1H), 0.44−0.30 (m, 1H). ^{13}C{1H} NMR (75 MHz, $CDCl_3$) δ 184.9, 155.5, 144.2, 139.6, 137.2, 129.4, 128.0, 125.0, 123.7, 119.7, 116.6, 115.5, 111.1, 61.0, 56.4, 47.5, 35.4, 26.7, 23.3, 21.8, 16.4. HRMS (ESI-TOF): Exact mass calcd for $C_{21}H_{21}N_2$ [M − H]$^-$: 301.1705, found 301.1713.

2-Methyl-2′,3′,3a′,5′-tetrahydro-1′*H*-spiro[indole-3,4′-pyrrolo[1,2-*a*]quinoline] (3ac′). Eluent: petroleum ether/ethyl acetate (10/1). Yellow solid, 57 mg, 50% yield, 3.5/1 dr (10/1 dr), mp 184−185 °C. ^{1}H NMR (300 MHz, DMSO-d_6) δ 7.42 (d, J = 6.9 Hz, 1H), 7.21 (t, J = 6.0 Hz, 1H), 6.90 (t, J = 6.9 Hz, 1H), 6.82 (d, J = 7.5 Hz, 1H), 6.37 (d, J = 6.6 Hz, 1H), 6.15−6.05 (m, 2H), 3.97−3.92 (m, 1H), 3.73 (s, 3H), 3.46 (t, J = 8.1 Hz, 1H), 3.40 (AB, J = 16.2 Hz, 1H), 3.07 (dd, J = 16.8, 8.7 Hz, 1H), 2.25 (s, 3H), 2.21 (AB, J = 16.5 Hz, 1H), 1.82−1.71 (m, 2H), 1.60−1.58 (m, 1H), 0.42−0.29 (m, 1H). ^{13}C{1H} NMR (75 MHz, DMSO-d_6) δ 184.9, 159.9, 155.5, 145.2, 139.6, 130.2, 128.1, 125.0, 123.7, 119.7, 111.0, 100.7, 96.7, 61.0, 56.6, 55.2, 47.7, 35.1, 26.8, 23.3, 16.4. HRMS (ESI-TOF): Exact mass calcd for $C_{21}H_{21}N_2O$ [M − H]$^-$: 317.1654, found 317.1663.

8′-Chloro-2-methyl-2′,3′,3a′,5′-tetrahydro-1′*H*-spiro[indole-3,4′-pyrrolo[1,2-*a*]quioline] (3ad′). Eluent: petroleum ether/ethyl acetate (10/1). White solid, 95 mg, 80% yield, 3.5/1 dr (8/1 dr), mp 168−169 °C. ^{1}H NMR (300 MHz, DMSO-d_6) δ 7.45 (d, J = 7.5 Hz, 1H), 7.25 (t, J = 7.5 Hz, 1H), 6.96−6.94 (m, 2H), 6.58−6.55 (m, 2H), 6.38 (d, J = 7.5 Hz, 1H), 4.00 (dd, J = 9.3, 5.7 Hz, 1H), 3.50 (t, J = 8.7 Hz, 1H), 3.40 (AB, J = 15.6 Hz, 1H), 3.09 (dd, J = 16.5, 8.4 Hz, 1H), 2.30 (AB, J = 15.3 Hz, 1H), 2.27 (s, 3H), 1.85−1.73 (m, 2H), 1.65−1.59 (m, 1H), 0.45−0.31 (m, 1H). ^{13}C{1H} NMR (75 MHz, DMSO-d_6) δ 184.5, 155.5, 145.5, 139.3, 132.7, 130.8, 128.2, 125.2, 123.5, 119.9, 117.4, 115.0, 109.6, 60.9, 55.8, 47.7, 35.1, 26.7, 23.3, 16.3. HRMS (ESI-TOF): Exact mass calcd for $C_{20}H_{18}N_2Cl$ [M − H]$^-$: 321.1159, found 321.1168.

8′-Bromo-2-methyl-2′,3′,3a′,5′-tetrahydro-1′*H*-spiro[indole-3,4′-pyrrolo[1,2-*a*]quinoline] (3ae′). Eluent: petroleum ether/ethyl acetate (10/1). Yellow solid, 103 mg, 77% yield, 3.5/1 dr (>20/1 dr), mp 154−155 °C. ^{1}H NMR (300 MHz, DMSO-d_6) δ 7.45 (d, J = 7.8 Hz, 1H), 7.25 (t, J = 7.5 Hz, 1H), 6.95 (t, J = 7.5 Hz, 1H), 6.89 (d, J = 7.8 Hz, 1H), 6.71−6.68 (m 2H), 6.38 (d, J = 7.5 Hz, 1H), 3.99 (dd, J = 9.6, 5.7 Hz, 1H), 3.50 (t, J = 8.4 Hz, 1H), 3.38 (AB, J = 15.9 Hz, 1H), 3.08 (dd, J = 16.8, 8.7 Hz, 1H), 2.29 (AB, J = 15.6 Hz, 1H), 2.27 (s, 3H), 1.87−1.73 (m, 2H), 1.65−1.57 (m, 1H), 0.45−0.30 (m, 1H). ^{13}C{1H} NMR (75 MHz, DMSO-d_6) δ 184.5, 155.5, 145.7, 139.3, 131.2, 128.3, 125.2, 123.5, 119.9, 118.0, 117.9, 112.4, 60.8, 55.8, 47.6, 35.1, 26.6, 23.3, 16.3. HRMS (ESI-TOF): Exact mass calcd for $C_{20}H_{20}N_2Br$ [M − H]$^-$: 367.0810, found 367.0819.

2-Methyl-7′-(trifluoromethyl)-2′,3′,3a′,5′-tetrahydro-1′*H*-spiro[indole-3,4′-pyrrolo[1,2-*a*]quinoline] (3af′). Eluent: petroleum ether/ethyl acetate (6/1). White solid, 112 mg, 86% yield, 3.5/1 dr (>20/1 dr), mp 155−156 °C. ^{1}H NMR (300 MHz, DMSO-d_6) δ 7.47 (d, J = 7.5 Hz, 1H), 7.25 (t, J = 7.5 Hz, 1H), 7.16 (d, J = 7.5 Hz, 1H), 6.95 (t, J = 7.5 Hz, 1H), 6.86 (d, J = 7.5 Hz, 1H), 6.78 (s, 1H), 6.35 (d, J = 7.2 Hz, 1H), 4.05 (dd, J = 9.6, 6.0 Hz, 1H), 3.57 (t, J = 9.0 Hz, 1H), 3.51 (AB, J = 16.2 Hz, 1H), 3.14 (dd, J = 16.8, 8.7 Hz, 1H), 2.40 (AB, J = 15.9 Hz, 1H), 2.29 (s, 3H), 1.87−1.77 (m, 2H), 1.68−1.60 (m, 1H), 0.48−0.33 (m, 1H). ^{13}C{1H} NMR (75 MHz, DMSO-d_6) δ 184.0, 155.1, 144.2, 138.8, 129.6, 128.6 (q, J = 31.5 Hz), 127.8, 124.8, 123.6 (q, J = 260.0 Hz), 122.9, 122.0, 119.4, 111.3 (q, J = 10.5 Hz), 105.4 (q, J = 5.3 Hz), 60.4, 55.0, 47.1, 34.9, 26.2, 22.8, 15.8. HRMS (ESI-TOF): Exact mass calcd for $C_{21}H_{18}F_3N_2$ [M − H]$^-$: 355.1422, found 355.1415.

7′-Chloro-2-methyl-2′,3′,3a′,5′-tetrahydro-1′*H*-spiro[indole-3,4′-pyrrolo[1,2-*a*]quinoline] (3ag′). Eluent: petroleum ether/ethyl acetate (10/1). White solid, 95 mg, 81% yield, 3.5/1 dr (>20/1 dr), mp 166−168 °C. ^{1}H NMR (300 MHz, DMSO-d_6) δ 7.46 (d, J = 7.5 Hz, 1H), 7.25 (t, J = 7.5 Hz, 1H), 6.96−6.95 (m, 2H), 6.58−6.55 (m, 2H), 6.38 (d, J = 7.2 Hz, 1H), 4.00 (dd, J = 9.3, 5.7 Hz, 1H), 3.50 (t, J = 8.7 Hz, 1H), 3.40 (AB, J = 15.6 Hz, 1H), 3.09 (dd, J = 16.8, 9.0 Hz, 1H), 2.30 (AB, J = 15.6 Hz, 1H), 2.27 (s, 3H), 1.85−1.73 (m, 2H), 1.66−1.60 (m, 1H), 0.46−0.32 (m, 1H). ^{13}C{1H} NMR (75 MHz, DMSO-d_6) δ 184.0, 155.0, 145.0, 138.8, 132.2, 130.3, 127.7, 124.7, 123.0, 119.3, 116.9, 114.5, 109.1, 60.3, 55.4, 47.2, 34.6, 26.2, 22.7, 15.8. HRMS (ESI-TOF): Exact mass calcd for $C_{20}H_{18}N_2Cl$ [M − H]$^-$: 321.1159, found 321.1148.

7′-Bromo-2-methyl-2′,3′,3a′,5′-tetrahydro-1′*H*-spiro[indole-3,4′-pyrrolo[1,2-*a*]quinoline] (3ah′). Eluent: petroleum ether/ethyl acetate (10/1). Pale yellow solid, 98 mg, 74% yield, 3.5/1 dr (15/1 dr), mp 122−124 °C. ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.56 (d, J = 7.8 Hz, 1H), 7.32−7.26 (m, 2H), 7.08 (s, 1H), 6.96 (t, J = 7.5 Hz, 1H), 6.53 (d, J = 7.2 Hz, 1H), 6.46 (d, J = 8.7 Hz, 1H), 3.93 (dd, J = 9.6, 5.7 Hz, 1H), 3.49 (t, J = 8.7 Hz, 1H), 3.39 (AB, J = 15.6 Hz, 1H), 3.20

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(dd, J = 16.5, 8.4 Hz, 1H), 2.41 (AB, J = 15.6 Hz, 1H), 2.32 (s, 3H), 1.93−1.78 (m, 2H), 1.69−1.60 (m, 1H), 0.72−0.58 (m, 1H). ^{13}C{1H} NMR (75 MHz, $CDCl_3$) δ 183.5, 154.9, 143.0, 138.6, 131.9, 130.7, 128.0, 125.3, 123.7, 120.0, 119.9, 111.7, 107.4, 61.3, 56.0, 47.5, 35.4, 26.7, 23.3, 16.2. HRMS (ESI-TOF): Exact mass calcd for $C_{20}H_{20}N_2Br$ $[M + H]^+$: 367.0810, found 367.0802.

2-Methyl-7′-nitro-2′,3′,3a′,5′-tetrahydro-1′*H*-spiro[indole-3,4′-pyrrolo[1,2-*a*]quinoline] (3ai′). Eluent: petroleum ether/ethyl acetate (6/1). Yellow solid, 110 mg, 92% yield, 3.5/1 dr (>20/1 dr), mp 176−177 °C.^{1}H NMR (300 MHz, DMSO-d_6) δ 8.11 (d, J = 8.7 Hz, 1H), 7.92 (s, 1H), 7.49 (d, J = 7.2 Hz, 1H), 7.28 (t, J = 7.5 Hz, 1H), 6.96 (t, J = 7.5 Hz, 1H), 6.72 (d, J = 8.7 Hz, 1H), 6.33 (d, J = 7.2 Hz, 1H), 4.17 (dd, J = 9.6, 5.4 Hz, 1H), 3.69 (t, J = 9.3 Hz, 1H), 3.51 (AB, J = 15.6 Hz, 1H), 3.25−3.18 (m, 1H), 2.50 (AB, J = 15.0 Hz, 1H), 2.30 (s, 3H), 1.93−1.78 (m, 2H), 1.69−1.65 (m, 1H), 0.50−0.36 (m, 1H). ^{13}C{1H} NMR (75 MHz, DMSO-d_6) δ 183.9, 155.5, 149.6, 138.8, 136.0, 128.6, 125.7, 125.6, 125.5, 123.2, 120.1, 118.9, 109.9, 61.5, 55.4, 48.3, 34.9, 26.6, 23.1, 16.3. HRMS (ESI-TOF): Exact mass calcd for $C_{20}H_{19}N_3O_2Na$ $[M + Na]^+$: 356.1375, found 356.1386.

2,5-Dimethyl-2′,3′,3a′,5′-tetrahydro-1′*H*-spiro[indole-3,4′-pyrrolo[1,2-*a*]quinoline] (3ba′). Eluent: petroleum ether/ethyl acetate (10/1). White solid, 70 mg, 64% yield, 3.5/1 dr (12/1 dr), mp 120−121 °C. ^{1}H NMR (300 MHz, DMSO-d_6) δ 7.32 (d, J = 7.8 Hz, 1H), 7.16 (t, J = 7.5 Hz, 1H), 7.03 (d, J = 7.5 Hz, 1H), 6.94 (d, J = 7.2 Hz, 1H), 6.60−6.53 (m, 2H), 6.20 (s, 1H), 3.95 (dd, J = 9.6, 6.0 Hz, 1H), 3.47 (t, J = 8.4 Hz, 1H), 3.43 (AB, J = 15.3 Hz, 1H), 3.10 (dd, J = 16.2, 8.4 Hz, 1H), 2.32 (AB, J = 16.8 Hz, 1H), 2.24 (s, 3H), 2.05 (s, 3H), 1.84−1.70 (m, 2H), 1.64−1.56 (m, 1H), 0.48−0.34 (m, 1H). ^{13}C{1H} NMR (75 MHz, DMSO-d_6) δ 183.1, 152.9, 143.9, 139.4, 133.3, 129.1, 128.0, 127.8, 124.0, 118.7, 117.8, 115.2, 110.0, 60.4, 55.6, 47.1, 35.1, 26.2, 22.8, 21.1, 15.7. HRMS (ESI-TOF): Exact mass calcd for $C_{21}H_{21}N_2$ $[M - H]^-$: 301.1705, found 301.1716.

5-Methoxy-2-methyl-2′,3′,3a′,5′-tetrahydro-1′*H*-spiro-[indole-3,4′-pyrrolo[1,2-*a*]quinoline] (3ca′). Eluent: petroleum ether/ethyl acetate (10/1). Pale yellow solid, 108 mg, 93% yield, 3.5/1 dr (8/1 dr), mp 112−114 °C. ^{1}H NMR (300 MHz, DMSO-d_6) δ 7.34 (d, J = 8.4 Hz, 1H), 7.16 (t, J = 7.5 Hz, 1H), 6.94 (d, J = 7.2 Hz, 1H), 6.78 (dd, J = 8.4, 2.4 Hz, 1H), 6.59−6.35 (m, 2H), 5.91 (d, J = 2.4 Hz, 1H), 3.98 (dd, J = 9.6, 5.7 Hz, 1H), 3.52 (m, 1H), 3.48 (s, 3H), 3.43 (AB, J = 15.6 Hz, 1H), 3.08 (dd, J = 16.5, 9.0 Hz, 1H), 2.27 (AB, J = 15.6 Hz, 1H), 2.22 (s, 3H), 1.92−1.71 (m, 2H), 1.66−1.58 (m, 1H), 0.50−0.36 (m, 1H). ^{13}C{1H} NMR (75 MHz, DMSO-d_6) δ 183.7, 158.5, 150.6, 145.8, 142.4, 131.1, 129.8, 121.2, 120.0, 117.1, 113.2, 112.5, 111.7, 62.5, 57.5, 56.8, 49.2, 37.1, 28.2, 24.8, 17.6. HRMS (ESI-TOF): Exact mass calcd for $C_{21}H_{21}N_2O$ $[M - H]^-$: 317.1654, found 317.1662.

5-Chloro-2-methyl-2′,3′,3a′,5′-tetrahydro-1′*H*-spiro[indole-3,4′-pyrrolo[1,2-*a*]quinoline] (3da′). Eluent: petroleum ether/ethyl acetate (10/1). Pale yellow solid, 61 mg, 64% yield, 3.5/1 dr (15/1 dr), mp 120−121 °C (0.3 mmol). ^{1}H NMR (300 MHz, DMSO-d_6) δ 7.47 (d, J = 8.1 Hz, 1H), 7.30 (d, J = 7.8 Hz, 1H), 7.19 (t, J = 7.2 Hz, 1H), 6.97 (d, J = 6.9 Hz, 1H), 6.62−6.56 (m, 2H), 6.31 (s, 1H), 3.98 (dd, J = 9.0, 5.7 Hz, 1H), 3.49 (m, 1H), 3.46 (AB, J = 15.6 Hz, 1H), 3.11 (dd, J = 16.2, 8.1 Hz, 1H), 2.32 (AB, J = 15.6 Hz, 1H), 2.28 (s, 3H), 1.86−1.71 (m, 2H), 1.66−1.60 (m, 1H), 0.45−0.31 (m, 1H). ^{13}C{1H} NMR (75 MHz, DMSO-d_6) δ 185.4, 153.9, 143.6, 141.2, 129.2, 129.1, 128.1, 127.7, 127.0, 123.2, 120.5, 117.4, 115.5, 110.0, 60.4, 56.4, 47.1, 34.9, 26.2, 22.7, 15.9. HRMS (ESI-TOF): Exact mass calcd for $C_{20}H_{18}N_2Cl$ $[M - H]^-$: 321.1159, found 321.1169.

8′-Chloro-2,5-dimethyl-2′,3′,3a′,5′-tetrahydro-1′*H*-spiro-[indole-3,4′-pyrrolo[1,2-*a*]quinoline] (3bd′). Eluent: petroleum ether/ethyl acetate (10/1). Pale yellow solid, 105 mg, 86% yield, 3.5/1 dr (>20/1 dr), mp 163−164 °C. ^{1}H NMR (300 MHz, DMSO-d_6) δ 7.33 (d, J = 7.8 Hz, 1H), 7.05 (d, J = 7.5 Hz, 1H), 6.95 (d, J = 7.5 Hz, 1H), 6.59−6.55 (m, 2H), 6.20 (s, 1H), 3.96 (dd, J = 9.6, 5.7 Hz, 1H), 3.49 (t, J = 8.1 Hz, 1H), 3.38 (AB, J = 15.6 Hz, 1H), 3.10 (dd, J = 16.5, 8.7 Hz, 1H), 2.28 (AB, J = 15.6 Hz, 1H), 2.24 (s, 3H), 2.09 (s, 3H), 1.88−1.76 (m, 2H), 1.64−1.56 (m, 1H), 0.48−0.34 (m, 1H). ^{13}C{1H} NMR (75 MHz, DMSO-d_6) δ 182.8, 152.9, 145.0, 139.1, 133.6, 132.1, 130.3, 128.2, 123.7, 118.9, 116.9, 114.5, 109.1, 60.3, 55.3, 47.1, 34.5, 26.1, 22.7, 21.1, 15.7. HRMS (ESI-TOF): Exact mass calcd for $C_{21}H_{20}N_2Cl$ $[M - H]^-$: 335.1315, found 335.1325.

2,5-Dimethyl-7′-nitro-2′,3′,3a′,5′-tetrahydro-1′*H*-spiro-[indole-3,4′-pyrrolo[1,2-*a*]quinoline] (3bi′). Eluent: petroleum ether/ethyl acetate (6/1). Yellow solid, 115 mg, 90% yield, 3.5/1 dr (>20/1 dr), mp 216−218 °C. ^{1}H NMR (300 MHz, DMSO-d_6) δ 8.12 (d, J = 7.8 Hz, 1H), 7.92 (s, 1H), 7.36 (d, J = 7.2 Hz, 1H), 7.08 (d, J = 7.2 Hz, 1H), 6.72 (d, J = 8.7 Hz, 1H), 6.13 (s, 1H), 4.16−4.14 (m, 1H), 3.68 (t, J = 7.8 Hz, 1H), 3.48 (AB, J = 15.6 Hz, 1H), 3.24 (dd, J = 16.2, 8.7 Hz, 1H), 2.49 (AB, J = 15.3 Hz, 1H), 2.27 (s, 3H), 2.08 (s, 3H), 1.91−1.85 (m, 2H), 1.72−1.64 (m, 1H), 0.52−0.39 (m, 1H). ^{13}C{1H} NMR (75 MHz, DMSO-d_6) δ 182.7, 153.4, 149.6, 139.1, 136.0, 134.5, 129.0, 125.68, 125.65, 123.9, 119.7, 118.9, 109.9, 61.5, 55.3, 48.3, 34.9, 26.6, 23.1, 21.6, 16.2. HRMS (ESI-TOF): Exact mass calcd for $C_{21}H_{21}N_3O_2Na$ $[M + Na]^+$: 370.1531, found 370.1541.

7′-Chloro-5-methoxy-2-methyl-2′,3′,3a′,5′-tetrahydro-1′*H*-spiro[indole-3,4′-pyrrolo[1,2-*a*]quinoline] (3cg′). Eluent: petroleum ether/ethyl acetate (10/1). White solid, 106 mg, 83% yield, 3.5/1 dr (15/1 dr), mp 143−144 °C. ^{1}H NMR (300 MHz, DMSO-d_6) δ 7.35 (d, J = 8.4 Hz, 1H), 7.17 (dd, J = 8.4, 2.4 Hz, 1H), 7.01 (d, J = 1.5 Hz, 1H), 6.79 (dd, J = 8.4, 2.4 Hz, 1H), 6.56 (d, J = 8.4 Hz, 1H), 5.88 (d, J = 2.4 Hz, 1H), 3.97 (dd, J = 9.6, 5.7 Hz, 1H), 3.51 (s, 3H), 3.46 (m, 1H), 3.39 (AB, J = 15.6 Hz, 1H), 3.05 (dd, J = 16.5, 9.3 Hz, 1H), 2.30 (AB, J = 15.9 Hz, 1H), 2.21 (s, 3H), 1.85−1.71 (m, 2H), 1.65−1.57 (m, 1H), 0.48−0.34 (m, 1H). ^{13}C{1H} NMR (75 MHz, DMSO-d_6) δ 182.0, 157.2, 149.2, 143.2, 140.7, 129.1, 127.9, 120.3, 120.0, 119.0, 111.8, 111.5, 111.0, 61.0, 55.7, 55.4, 48.0, 35.3, 26.7, 23.3, 16.1. HRMS (ESI-TOF): Exact mass calcd for $C_{21}H_{20}ClN_2O$ $[M - H]^-$: 351.1264, found 351.1249.

5-Methoxy-2-methyl-7′-nitro-2′,3′,3a′,5′-tetrahydro-1′*H*-spiro[indole-3,4′-pyrrolo[1,2-*a*]quinoline] (3ci′). Eluent: petroleum ether/ethyl acetate (10/1). Yellow solid, 120 mg, 91% yield, 3.5/1 dr (>20/1 dr), mp 166−168 °C. ^{1}H NMR (300 MHz, DMSO-d_6) δ 8.11 (d, J = 9.0 Hz, 7.93 (s, 1H), 7.39 (d, J = 8.4 Hz, 1H), 6.83 (d, J = 8.4 Hz, 1H), 6.71 (d, J = 9.3 Hz, 1H), 5.83 (s, 1H), 4.15 (dd, J = 9.9, 5.7 Hz, 1H), 3.69 (t, J = 7.8 Hz, 1H), 3.51 (s, 3H), 3.46 (m, 1H), 3.23 (dd, J = 18.0, 9.0 Hz, 1H), 2.50 (AB, J = 15.6 Hz, 1H), 2.26 (s, 3H), 1.94−1.78 (m, 2H), 1.69−1.65 (m, 1H), 0.55−0.41 (m, 1H). ^{13}C{1H} NMR (75 MHz, DMSO-d_6) δ 181.3, 157.3, 149.5, 149.1, 140.2, 136.0, 125.7, 120.3, 118.7, 112.1, 110.6, 109.7, 61.6, 55.5, 55.4, 48.4, 35.0, 26.6, 23.1, 16.1. HRMS (ESI-TOF): Exact mass calcd for $C_{21}H_{21}N_3O_3Na$ $[M + Na]^+$: 386.1481, found 386.1492.

5-Chloro-2,8′-dimethyl-2′,3′,3a′,5′-tetrahydro-1′*H*-spiro-[indole-3,4′-pyrrolo[1,2-*a*]quinoline] (3db′). Eluent: petroleum ether/ethyl acetate (10/1). White solid, 62 mg, 61% yield, 3.5/1 dr (15/1 dr), mp 146−147 °C (0.3 mmol). ^{1}H NMR (300 MHz, DMSO-d_6) δ 7.45 (d, J = 8.1 Hz, 1H), 7.28 (dd, J = 8.1, 2.1 Hz, 1H), 6.84 (d, J = 7.5 Hz, 1H), 6.43−6.38 (m, 2H), 6.32 (d, J = 1.8 Hz, 1H), 3.93 (dd, J = 9.6, 6.0 Hz, 1H), 3.44 (t, J = 8.7 Hz, 1H), 3.39 (AB, J = 15.6 Hz, 1H), 3.11 (dd, J = 16.5, 8.7 Hz, 1H), 2.29 (AB, J = 15.6 Hz, 1H), 2.28 (s, 3H), 2.26 (s, 3H), 1.80−1.70 (m, 2H), 1.65−1.57 (m, 1H), 0.42−0.28 (m, 1H). ^{13}C{1H} NMR (75 MHz, DMSO-d_6) δ 187.4, 155.8, 145.4, 143.2, 138.8, 131.0, 129.5, 125.2, 124.3, 122.4, 118.4, 116.5, 112.6, 62.2, 58.6, 48.9, 36.5, 28.1, 24.6, 23.2, 17.9. HRMS (ESI-TOF): Exact mass calcd for $C_{21}H_{22}ClN_2$ $[M + H]^+$: 337.1472, found 337.1479.

8′-Bromo-5-chloro-2-methyl-2′,3′,3a′,5′-tetrahydro-1′*H*-spiro[indole-3,4′-pyrrolo[1,2-*a*]quinoline] (3de′). Eluent: petroleum ether/ethyl acetate (10/1). Yellow solid, 96 mg, 80% yield, 3.5/1 dr (>20/1 dr), mp 160−161 °C (0.3 mmol). ^{1}H NMR (300 MHz, DMSO-d_6) δ 7.48 (d, J = 8.1 Hz, 1H), 7.32 (d, J = 7.5 Hz, 1H), 6.92 (d, J = 7.5 Hz, 1H), 6.75−6.72 (m, 2H), 6.31 (s, 1H), 3.99 (dd, J = 9.6, 5.7 Hz, 1H), 3.48 (t, J = 8.7 Hz, 1H), 3.43 (AB, J = 15.9 Hz, 1H), 3.12 (dd, J = 16.2, 7.2 Hz, 1H), 2.34 (AB, J = 15.9 Hz, 1H), 2.28 (s, 3H), 1.86−1.73 (m, 2H), 1.69−1.61 (m, 1H), 0.46−0.32 (m, 1H). ^{13}C{1H} NMR (75 MHz, DMSO-d_6) δ 185.1, 153.8, 144.9, 141.0, 130.8, 129.2, 127.8, 123.0, 120.9, 120.6, 117.8, 117.0, 112.0, 60.2, 56.0, 47.1, 34.3, 26.1, 22.7, 15.9. HRMS (ESI-TOF): Exact mass calcd for $C_{20}H_{17}BrClN_2$ $[M - H]^-$: 399.0264, found 399.0273.

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5-Chloro-2-methyl-7′-nitro-2′,3′,3a′,5′-tetrahydro-1′*H*-spiro[indole-3,4′-pyrrolo[1,2-*a*]quinoline] (3di′). Eluent: petroleum ether/ethyl acetate (8/1). Yellow solid, 120 mg, 90% yield, 3.5/1 dr (>20/1 dr), mp 185−186 °C. ^{1}H NMR (300 MHz, DMSO-d_6) δ 8.14 (dd, J = 9.0, 2.1 Hz, 1H), 7.95 (s, 1H), 7.52 (d, J = 8.1 Hz, 1H), 7.35 (dd, J = 8.4, 1.8 Hz, 1H), 6.75 (d, J = 9.0 Hz, 1H), 6.23 (d, J = 1.5 Hz, 1H), 4.17 (dd, J = 10.2, 2.4 Hz, 1H), 3.69 (t, J = 8.7 Hz, 1H), 3.53 (AB, J = 15.6 Hz, 1H), 3.26 (dd, J = 19.2, 9.9 Hz, 1H), 2.57 (AB, J = 15.9 Hz, 1H), 2.31 (s, 3H), 1.95−1.82 (m, 2H), 1.73−1.68 (m, 1H), 0.52−0.41 (m, 1H). ^{13}C{1H} NMR (75 MHz, DMSO-d_6) δ 185.0, 154.3, 149.3, 141.0, 136.2, 129.9, 128.7, 125.8, 125.7, 123.2, 121.4, 118.5, 110.0, 61.3, 56.1, 48.2, 34.6, 26.6, 23.0, 16.3. HRMS (ESI-TOF): Exact mass calcd for $C_{20}H_{18}N_3O_2Cl$ [M + Na]$^+$: 390.0985, found 390.0993.

2-Ethyl-2′,3′,3a′,5′-tetrahydro-1′*H*-spiro[indole-3,4′-pyrrolo[1,2-*a*]quinolone] (3ea′). Eluent: petroleum ether/ethyl acetate (8/1). Yellow solid, 70 mg, 64% yield, 3.5/1 dr (5/1 dr), mp 151−153 °C. ^{1}H NMR (300 MHz, DMSO-d_6) δ 7.47 (d, J = 7.2 Hz, 1H), 7.22 (t, J = 7.2 Hz, 1H), 7.14 (t, J = 7.5 Hz, 1H), 7.94−6.85 (m, 2H), 6.58−6.54 (m, 2H), 6.36 (d, J = 7.2 Hz, 1H), 3.98 (dd, J = 9.0, 5.4 Hz, 1H), 3.46−3.42 (m, 2H), 3.08 (dd, J = 16.5, 8.4 Hz, 1H), 2.67−2.52 (m, 2H), 2.26 (d, J = 15.6 Hz, 1H), 1.82−1.57 (m, 3H), 1.29 (t, J = 7.2 Hz, 3H), 0.44−0.30 (m, 1H). ^{13}C{1H} NMR (75 MHz, DMSO-d_6) δ 188.5, 155.5, 144.3, 139.8, 129.6, 128.3, 128.1, 125.0, 123.7, 119.9, 118.5, 115.7, 110.4, 61.1, 56.2, 47.6, 35.7, 26.8, 23.3, 22.4, 10.8. HRMS (ESI-TOF): Exact mass calcd for $C_{21}H_{23}N_2$ [M + H]$^+$: 303.1861, found 303.1870.

3,3′-((2-(Piperidin-1-yl)phenyl)methylene)bis(2-methyl-1*H*-indole) (4a). Eluent: petroleum ether/ethyl acetate (8/1). White solid, 70 mg, 89% yield, mp 228−230 °C. ^{1}H NMR (300 MHz, DMSO-d_6) δ 10.59 (s, 2H), 7.30 (d, J = 7.5 Hz, 1H), 7.18−7.11 (m, 4H), 6.93 (t, J = 7.5 Hz, 1H), 6.88−6.83 (m, 4H), 6.64 (t, J = 7.5 Hz, 2H), 6.37 (s, 1H), 2.64 (s, 4H), 2.03 (s, 6H), 1.40 (s, 6H). ^{13}C{1H} NMR (75 MHz, DMSO-d_6) δ 152.6, 140.8, 135.5, 132.0, 131.2, 129.1, 127.2, 123.5, 121.4, 119.8, 118.7, 118.3, 113.7, 110.7, 54.2, 33.9, 26.9, 24.3, 12.4. HRMS (ESI-TOF): Exact mass calcd for $C_{30}H_{30}N_3$ [M − H]$^-$: 432.2440, found 432.2450.

4-(2-(Bis(2-methyl-1*H*-indol-3-yl)methyl)phenyl)morpholine (4b). Eluent: petroleum ether/ethyl acetate (8/1). White solid, 77 mg, 96% yield, mp 217−218 °C. ^{1}H NMR (300 MHz, DMSO-d_6) δ 10.64 (s, 2H), 7.30 (d, J = 7.2 Hz, 1H), 7.20−7.17 (m, 4H), 6.99 (m 1H), 6.88−6.85 (m, 4H), 6.67 (t, J = 7.2 Hz, 2H), 6.40 (s, 1H), 3.47 (s, 4H), 2.63 (s, 4H), 2.05 (s, 6H). ^{13}C{1H} NMR (75 MHz, DMSO-d_6) δ 150.8, 140.6, 134.9, 131.6, 130.6, 128.5, 126.9, 123.7, 121.2, 119.4, 118.1, 117.9, 113.0, 110.2, 66.8, 52.7, 33.6, 11.9. HRMS (ESI-TOF): Exact mass calcd for $C_{29}H_{28}N_3O$ [M − H]$^-$: 434.2232, found 434.2243.

■ ASSOCIATED CONTENT

Ⓢ Supporting Information

^{1}H and ^{13}C NMR spectra for all new compounds and X-ray structure information for **3ac′**. This material is available free of charge via the Internet at http://pubs.acs.org.

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Notes

The authors declare no competing financial interest.

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