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Rhodium-Catalyzed C−H Alkylation of Indolines with Allylic Alcohols: Direct Access to β-Aryl Carbonyl Compounds

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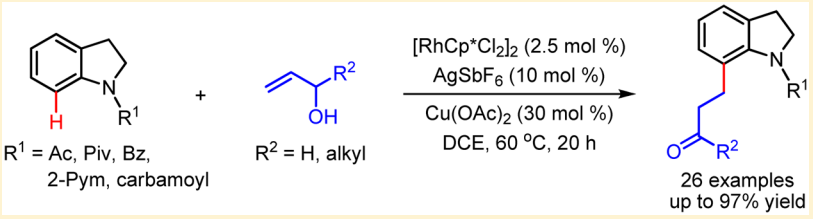
Supporting Information



ABSTRACT: The rhodium(III)-catalyzed site-selective C−H alkylation of various *N*-heterocycles, such as indolines, carbazoles, and pyrroles with readily available allylic alcohols is described. This protocol allows the generation of a heterocyclic scaffold containing a β-aryl carbonyl moiety, which is known to be a crucial structural unit of biologically active compounds.

The β-aryl ketones are among the most versatile synthetic precursors in organic and medicinal chemsitry[1] and are important structural motifs found in a range of bioactive natural products and pharmaceuticals, such as zingerone, (*S*)-gingerol, nabumetone, protein kinase inhibitor, 15-keto latanoprost, and non-nucleoside reverse transcriptase inhibitor (Figure 1).[2] The well-known methods for the preparation of β-aryl ketones are oxidative Heck reactions between aryl nucleophiles and allylic alcohols,[3] 1,4-addition reactions of stoichiometric organozinc reagents with enones,[4] and chemoselective reduction of β-aryl unsaturated ketones.[5] Notably, Sigman et al. made a significant breakthrough in the Pd(II)-catalyzed enantioselective Heck arylations of acyclic alkenyl alcohols using aryldiazonium salts as arene surrogates.[3e] Since the pioneering discovery of Miyaura in 1997, significant efforts have been devoted toward the rhodium-catalyzed conjugated addition reaction between arylboronic acids and α,β-unsaturated carbonyl compounds.[6] In addition, the decarboxylative Heck reaction of aryl carboxylic acids with allylic alcohols under palladium catalysis was reported.[7] The redox isomerization of β-aryl allylic alcohols under metal catalysis was also established.[8]

Transition-metal-catalyzed C−H functionalization has recently emerged as a powerful tool for various C−H and C−X bond formation reactions.[9] Notably, a great deal of effort has been devoted to the direct C−H allylations of (hetero)aromatic compounds with allylic acetates, allylic carbonates, and allenes under various metal catalysis.[10] However, the direct C−H alkylation of arenes with allylic alcohols for the formation of β-aryl ketones and aldehydes, despite its critical importance, has rarely been realized. Allylic alcohols have long served as versatile substrates for the construction of carbon frameworks due to their commerical availability, low cost, and easy preparation and handling. Notably, allylic alcohols have been used as the chemical equivalent of α,β-unsaturated ketones and aldehydes in most of these catalytic reactions.[11]

Recently, Jiang and co-workers revealed that *o*-C−H bonds of benzamides and acetanilides could be alkylated with allylic alcohols under rhodium and ruthenium catalysis in the presence of copper salt.[12] Meanwhile, the formation of β-aryl carbonyl compounds using electron-rich heteroarenes and allylic alcohols was also described.[13] Glorius et al. also reported the Rh(III)-catalyzed *o*-C−H activation of indoles and aryl ketones with allylic alcohols affording β-indolyl aldehydes and 2-acetylindenes, respectively.[14] Jeganmohan and co-workers disclosed the Ru(II)-catalyzed cyclization of *N*-substituted benzamides with allylic alcohols for the construction of an isoindolinone framework.[15] In sharp contrast to Rh(III) catalyst, Kanai recently demonstrated the unique reactivity of Co(III) catalyst for the coupling of indoles with allylic alcohols, giving C2-allylated indoles instead of β-indolyl carbonyl compounds.[16] In continuation of a recent study on the catalytic C−H bond functionalizations of indoline C7-position,[17] we present herein the Rh(III)-catalyzed direct C−H alkylation of indolines, carbazoles, and pyrroles with various allylic alcohols, affording the corresponding β-aryl carbonyl compounds.

Our investigation started with the coupling of 1-(indolin-1-yl)ethanone (**1a**) and but-3-en-2-ol (**2a**) using $[RhCp^*Cl_2]_2$ and $AgSbF_6$ in DCE (see Supporting Information for optimization table). To our delight, a cationic Rh(III) catalyst

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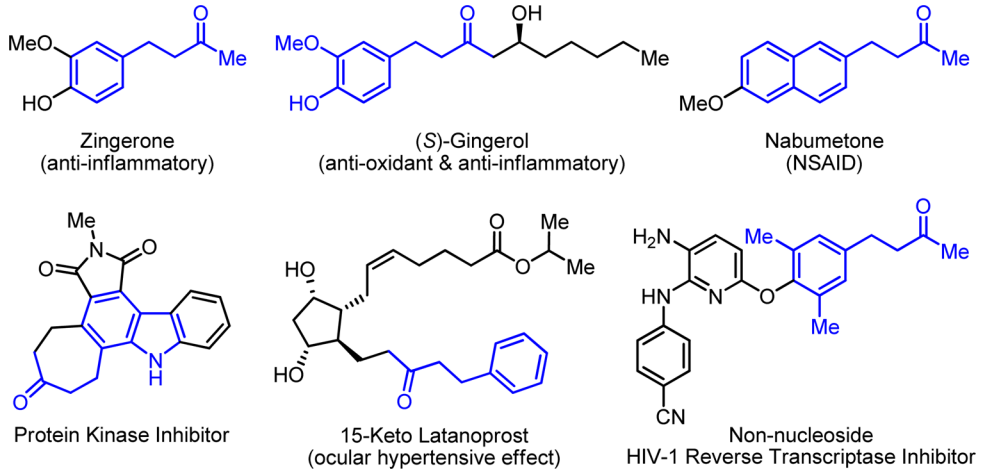
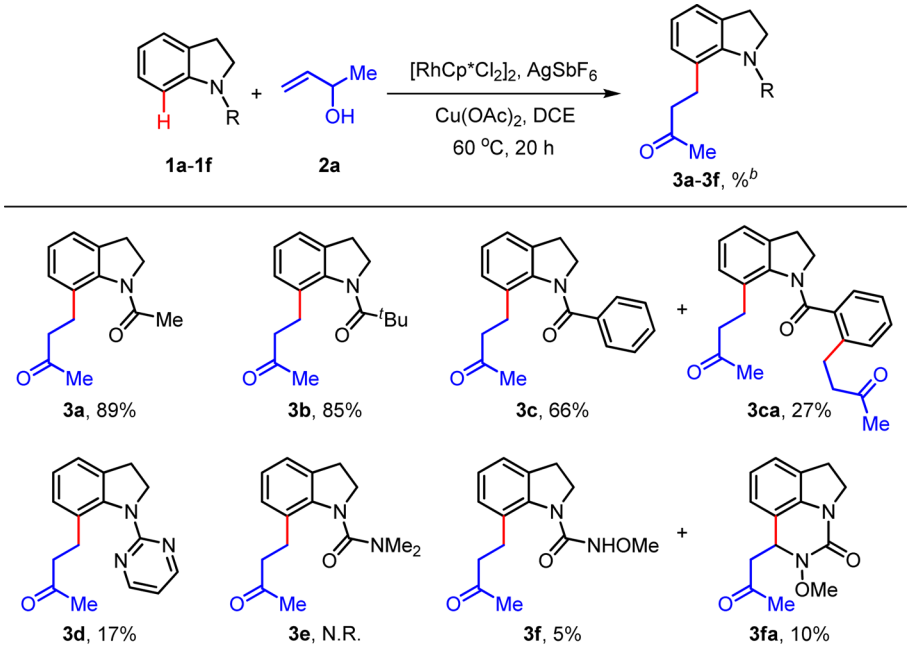


Figure 1. Selected bioactive molecules containing a β-aryl ketone moiety.

Table 1. Scope of Indolinic Protection Groups[a]



[a]Reaction conditions: **1a−1f** (0.3 mmol), **2a** (0.9 mmol), $[RhCp^*Cl_2]_2$ (2.5 mol %), $AgSbF_6$ (10 mol %), $Cu(OAc)_2$ (30 mol %), DCE (1 mL) under air at 60 °C for 20 h in reaction tubes. [b]Isolated yield by flash column chromatography.

was found to promote the coupling to afford β-indolinic ketone **3a** in 27% yield. Further screening of catalysts, such as Ru(II), Co(III), and Pd(II), was found to be ineffective in this coupling reaction. Further studies showed that 100 mol % of $Cu(OAc)_2$ additive displayed increased catalytic activity to deliver **3a** in 89% yield. Interestingly, the use of a decreased amount of $Cu(OAc)_2$ from 100 to 30 mol % provided a comparable yield of our desired product **3a**. However, neutral Rh(III) catalyst was found to be less effective in the current reaction system. Solvents such as THF, MeCN, MeOH, and DMSO failed to facilitate the coupling of **1a** and **2a**. Finally, lowering the amount of allylic alcohol **2a** provided a decreased formation of β-indolinic ketone **3a**.

With the optimized reaction conditions in hand, the coupling of indolines **1b−1f** containing various protecting groups with **2a** were examined (Table 1). First, *N*-pivaloyl indoline (**1b**) was found to be a good substrate for this coupling reaction to give corresponding product **3b** in 85% yield. However, the benzoyl protecting group provided the desired C7-monoalkylated indoline **3c** (66%) in addition to unexpected bisalkylated compound **3ca** (27%). In addition, the widely used 2-pyrimidinyl and *N*,*N*-dimethyl carbamoyl directing groups **1d** and **1e** showed less reactivity under the present reaction conditions. Interestingly, indoline **1f**, having an *N*-methoxycarbamoyl group, was coupled with **2a** to furnish C7-alkylated product **3f** concomitant with pharmaceutically important tricyclic compound **3fa**, albeit in low yield.[18]

To explore the substrate scope and limitation of this reaction, we screened a broad range of indolines (**1g−1s**) to couple with **2a**, as shown in Table 2. To our pleasure, C4-, C5-, and C6-substituted indolines **1g−1j** proved to be good substrates for this transformation affording the corresponding products **3g−3j** in high yields. However, C6-chloro-substituted indoline **1k** was found to be less reactive under the optimal reaction

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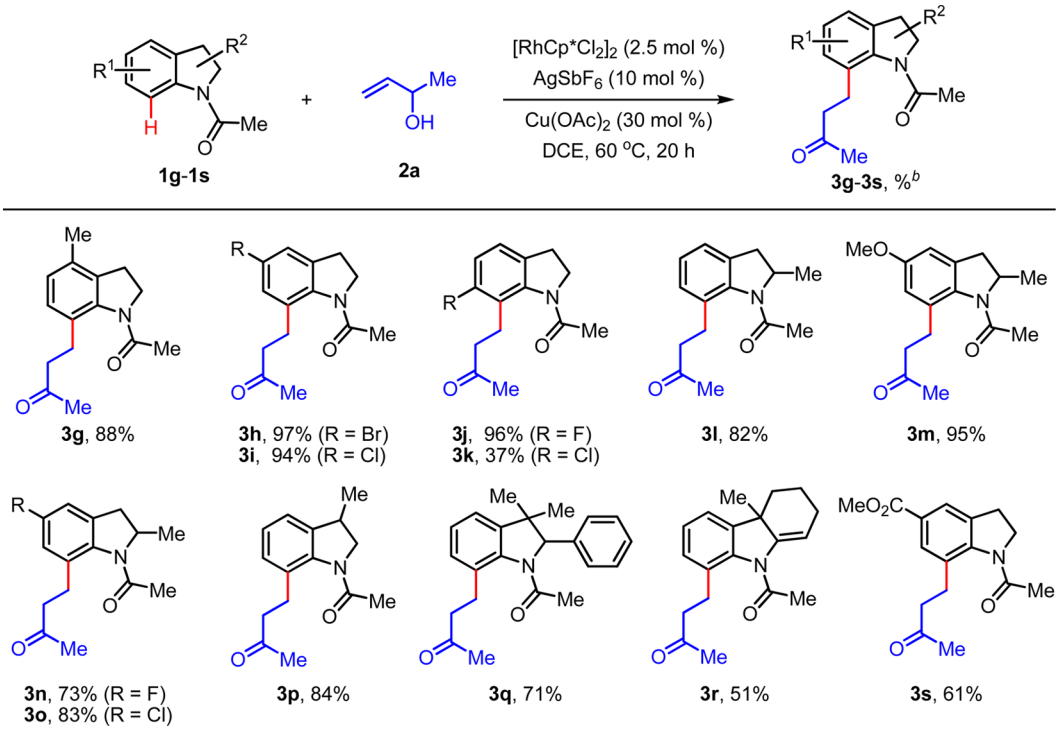
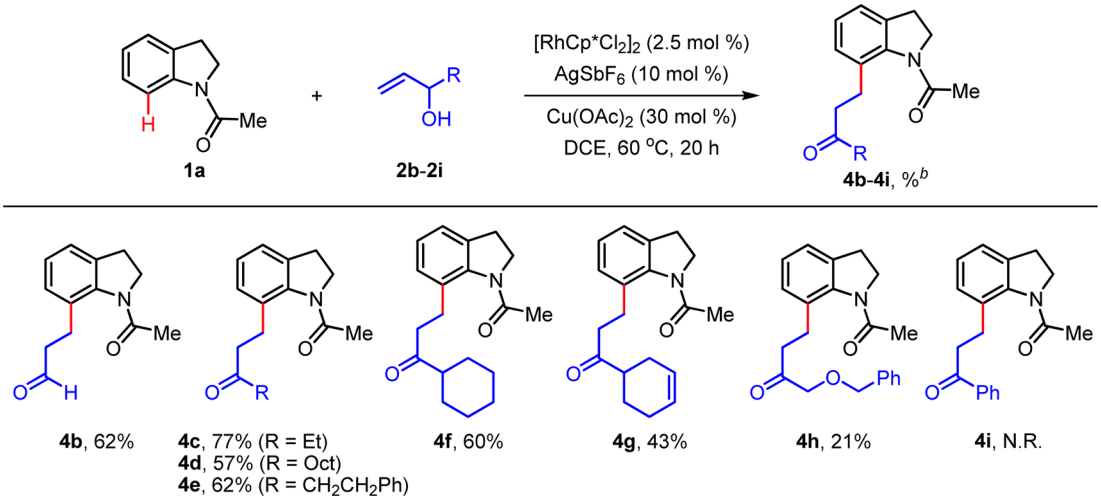
Table 2. Scope of Indolines[a]



[a]Reaction conditions: **1g−1s** (0.3 mmol), **2a** (0.9 mmol), $[RhCp^*Cl_2]_2$ (2.5 mol %), $AgSbF_6$ (10 mol %), $Cu(OAc)_2$ (30 mol %), DCE (1 mL) under air at 60 °C for 20 h in reaction tubes. [b]Isolated yield by flash column chromatography.

Table 3. Scope of Allylic Alcohols[a]



[a]Reaction conditions: **1a** (0.3 mmol), **2b−2i** (0.9 mmol), $[RhCp^*Cl_2]_2$ (2.5 mol %), $AgSbF_6$ (10 mol %), $Cu(OAc)_2$ (30 mol %), DCE (1 mL) under air at 60 °C for 20 h in reaction tubes. [b]Isolated yield by flash column chromatography.

conditions to afford **3k** in 37% yield. In addition, mono- or disubstituted indolines **1l−1r** at the C2- and C3-positions were found to undergo the redox-neutral alkylation reaction to provide **3l−3r** in good to high yields. Furthermore, indoline substrate **1s** with a truly functionalized group, i.e., CO_2Me, was smoothly coupled with allylic alcohol **2a** to give **3s** in 61% yield.

Next, α-substituted allylic alcohols were explored under the optimal reaction conditions with **1a** (Table 3). To our delight, allylic alcohol (**2b**) delivered β-indolinic aldehyde **4b** in 62% yield. Further investigation showed that the coupling of linear or branched α-alkyl substituted allylic alcohols **2c−2g** with **1a** provided the corresponding β-aryl ketones **4c−4g** in moderate to good yields. However, benzyloxy-substituted allylic alcohol **2h** was found to be less reactive to form **4h** in 21% yield. Unfortunately, α-aryl-substituted allylic alcohol **2i** did not undergo the cross coupling reaction under the current reaction conditions. It is noted that β- and γ-substituted allylic alcohols, such as 2-methylprop-2-en-1-ol and (*E*)-but-2-en-1-ol, were unreactive.

The scope of this reaction with respect to carbazoles and pyrroles was also explored (Scheme 1). Initially, *N*-acetyl carbazole (**5a**) was employed to couple with **2a**, but unfortunately, no coupling reaction was observed. However, carbazole **5b** with a 2-pyrimidinyl directing group provided the

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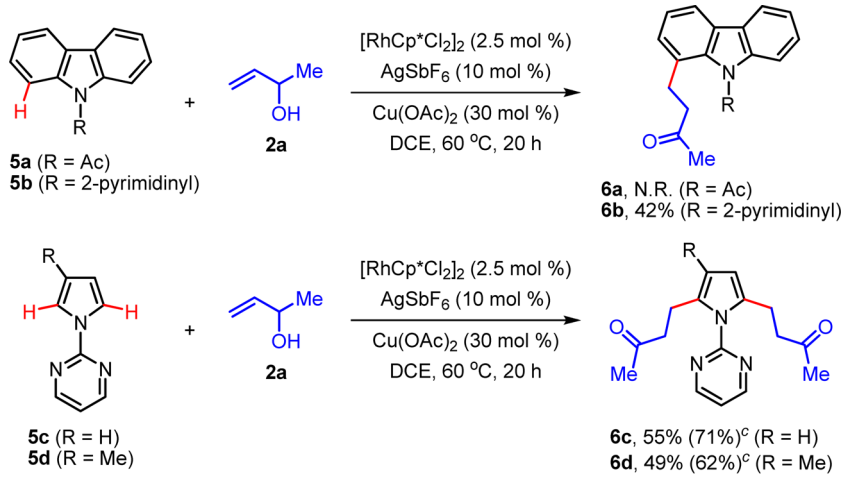
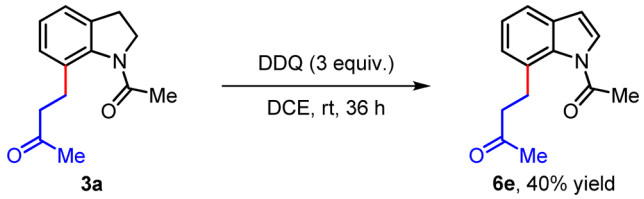
Scheme 1. Coupling of Allylic Alcohol with Carbazoles and Pyrroles[a]



[a]Reaction conditions: **5a**–**5d** (0.3 mmol), **2a** (0.9 mmol), $[RhCp^*Cl_2]_2$ (2.5 mol %), $AgSbF_6$ (10 mol %), $Cu(OAc)_2$ (30 mol %), DCE (1 mL) under air at 60 °C for 20 h in reaction tubes. [b]Isolated yield by flash column chromatography. [c]**2a** (1.5 mmol, 5 equiv) was used.

desired coupling reaction to afford the corresponding product **6b** in 42% yield under the optimized reaction conditions. Furthermore, pyrrole **5c** and 3-methyl pyrrole **5d** containing a 2-pyrimidinyl directing group also participated in this catalytic reaction, furnishing bis-alkylated products **6c** and **6d** in moderate yields, and no monoalkylated products were detected. Thus, increasing the amount of allylic alcohol **2a** furnished the corresponding products **6c** (71%) and **6d** (62%). In addition, we performed the oxidation of **3a** by using DDQ to deliver C7-alkylated indole **6e** in 40% yield (Scheme 2).

Scheme 2. Oxidation of 7-Alkylated Indoline

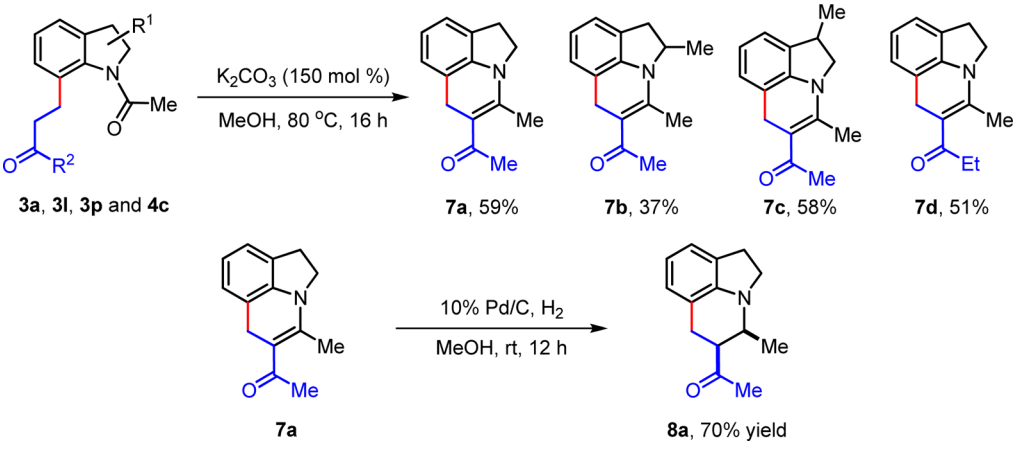


To highlight the synthetic utility of *β*-indolinic carbonyl compounds, we performed the intramolecular cyclization of *β*-indolinic carbonyl compounds under basic conditions to form a tricyclic indolinic compound known as biologically active pharmacophore.[19] Gratifyingly, the desired products **7a**–**7d** were obtained in moderate yields via an intramolecular aldol reaction followed by a subsequent dehydration reaction (Scheme 3). Finally, catalytic hydrogenation of **7a** provided the reduced tricylic indoline **8a** in 70% yield.

A proposed mechanistic pathway for the Rh(III)-catalyzed alkylation reaction of indolines with allylic alcohols is depicted in Scheme 4. A cationic Rh(III) catalyst can coordinate to a carbonyl moiety of **1a**, affording cyclorhodated intermediate **A**, which undergoes coordination with **2a** and subsequent 1,2-migratory insertion to generate intermediate **B**. Finally, *β*-H elimination affords the corresponding enol product **C**, which subsequently undergoes keto–enol tautomerization to give *β*-aryl ketone **3a**.[12]

In conclusion, we demonstrated the rhodium(III)-catalyzed C–H alkylations of indolines, carbazoles, and pyrroles with allylic alcohols to afford *β*-aryl carbonyl heterocycles. In addition, this protocol provides opportunity to generate 1,7-fused tricyclic indolinic compounds, which are known to be a crucial structural unit of biologically active compounds.

Scheme 3. Transformation of *β*-Indolinic Carbonyl Compounds



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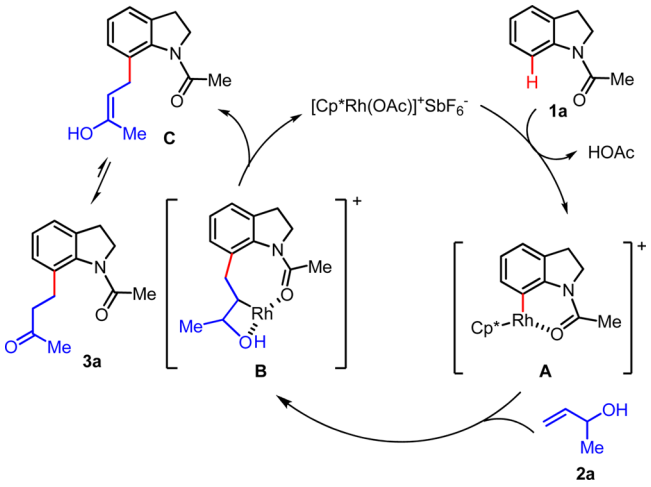
Scheme 4. Proposed Reaction Mechanism



EXPERIMENTAL SECTION

General Procedure for the Alkylation of *N*-Acetyl Indolines, *N*-(2-Pyrimidinyl)carbazoles, and *N*-(2-Pyrimidinyl)pyrroles (3a–3s, 4b–4h, and 6b–6d). To an oven-dried sealed tube charged with *N*-acetyl indoline (**1a**) (48.4 mg, 0.3 mmol, 100 mol %), $[RhCp^*Cl_2]_2$ (4.6 mg, 2.5 mol %), $AgSbF_6$ (10.3 mg, 10 mol %), and $Cu(OAc)_2$ (16.3 mg, 30 mol %) were added 3-buten-2-ol (**2a**) (64.9 mg, 0.9 mmol, 300 mol %) and DCE (1 mL). The reaction mixture was allowed to stir at 60 °C for 20 h. The reaction mixture was diluted with EtOAc (3 mL) and concentrated in vacuo. The residue was purified by flash column chromatography (silica gel, *n*-hexanes/EtOAc = 1:1 to 1:2) to afford 61.9 mg of **3a** in 89% yield.

4-(1-Acetylindolin-7-yl)butan-2-one (3a). White solid; 61.9 mg (89%); mp 89–90 °C; ^{1}H NMR (700 MHz, $CDCl_3$) δ 7.06–7.00 (m, 3H), 4.04 (t, J = 6.8 Hz, 2H), 2.99 (t, J = 7.4 Hz, 2H), 2.88 (t, J = 7.1 Hz, 2H), 2.78 (t, J = 8.0 Hz, 2H), 2.26 (s, 3H), 2.12 (s, 3H); ^{13}C NMR (175 MHz, $CDCl_3$) δ 208.9, 168.8, 140.8, 134.8, 131.7, 128.4, 125.5, 122.3, 51.2, 43.6, 29.9, 29.8, 27.9, 23.9; IR (KBr) υ 2919, 1708, 1659, 1590, 1449, 1384, 1352, 1221, 1188, 1160, 1109, 1032, 1017, 918, 850, 778 cm^{-1}; HRMS (Orbitrap, ESI) m/z calcd for $C_{14}H_{18}NO_2$ $[M + H]^+$ 232.1338, found 232.1326.

4-(1-Pivaloylindolin-7-yl)butan-2-one (3b). Brown sticky solid; 70.0 mg (85%); ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.08–7.07 (m, 1H), 7.04–7.00 (m, 2H), 4.09 (t, J = 7.4 Hz, 2H), 3.01 (t, J = 7.3 Hz, 2H), 2.79–2.71 (m, 4H), 2.13 (s, 3H), 1.38 (s, 9H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 208.8, 178.8, 142.7, 134.4, 132.0, 128.0, 125.9, 122.1, 51.2, 42.8, 40.0, 31.1, 29.7, 28.5, 27.5; IR (KBr) υ 2962, 1712, 1649, 1591, 1447, 1399, 1347, 1322, 1221, 1182, 1150, 1092, 1031, 904, 851 cm^{-1}; HRMS (Orbitrap, ESI) m/z calcd for $C_{17}H_{24}NO_2$ $[M + H]^+$ 274.1807, found 274.1792.

4-(1-Benzoylindolin-7-yl)butan-2-one (3c). White sticky solid; 58.1 mg (66%); ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.72 (d, J = 6.9 Hz, 2H), 7.51 (tt, J = 7.3, 1.3 Hz, 1H), 7.47–7.44 (m, 2H), 7.12–7.06 (m, 3H), 4.07 (t, J = 7.5 Hz, 2H), 2.99 (t, J = 7.4 Hz, 2H), 2.92–2.89 (m, 2H), 2.85–2.82 (m, 2H), 2.10 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 208.7, 170.3, 141.2, 136.1, 134.9, 131.8, 131.3, 128.6, 128.5, 128.3, 125.2, 122.4, 54.1, 43.1, 30.4, 29.8, 27.5; IR (KBr) υ 2922, 1711, 1649, 1592, 1447, 1364, 1251, 1160, 1024, 932, 878, 752 cm^{-1}; HRMS (Orbitrap, ESI) m/z calcd for $C_{19}H_{20}NO_2$ $[M + H]^+$ 294.1494, found 294.1480.

4-(1-(2-(3-Oxobutyl)benzoyl)indolin-7-yl)butan-2-one (3ca). Light brown sticky solid; 29.4 mg (27%); ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.40–7.35 (m, 2H), 7.29–7.27 (m, 2H), 7.12–7.07 (m, 3H), 3.84 (br s, 2H), 3.01–2.96 (m, 6H), 2.86–2.83 (m, 4H), 2.12 (s, 3H), 2.11 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 208.5, 207.8, 169.9, 141.8, 140.7, 139.3, 136.7, 135.3, 130.2, 130.1, 128.4, 127.6, 126.4, 126.0, 120.5, 53.2, 45.2, 43.5, 30.2, 29.9, 29.8, 27.7, 27.3; IR (KBr) υ 2922, 1708, 1649, 1590, 1447, 1366, 1252, 1160, 1038, 957, 879, 754 cm^{-1}; HRMS (Orbitrap, ESI) m/z calcd for $C_{23}H_{26}NO_3$ $[M + H]^+$ 364.1913, found 364.1894.

4-(1-(Pyrimidin-2-yl)indolin-7-yl)butan-2-one (3d). Yellow sticky oil; 13.5 mg (17%); ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.40 (d, J = 4.7 Hz, 2H), 7.10 (d, J = 7.0 Hz, 1H), 7.06–7.00 (m, 2H), 6.69 (t, J = 4.8 Hz, 1H), 4.42 (t, J = 7.6 Hz, 2H), 3.04 (t, J = 7.6 Hz, 2H), 2.91–2.88 (m, 2H), 2.74–2.71 (m, 2H), 2.04 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 208.6, 161.2, 157.6, 142.3, 135.1, 131.0, 128.1, 124.5, 122.5, 112.4, 53.3, 43.1, 29.9, 29.8, 28.1; IR (KBr) υ 2894, 1712, 1577, 1550, 1454, 1424, 1360, 1281, 1160, 1049, 990, 854, 799 cm^{-1}; HRMS (Orbitrap, ESI) m/z calcd for $C_{16}H_{18}N_3O$ $[M + H]^+$ 268.1450, found 268.1436.

***N*-Methoxy-7-(3-oxobutyl)indoline-1-carboxamide (3f).** Brown sticky oil; 3.9 mg (5%); ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.63 (d, J = 8.1 Hz, 1H), 7.18–7.15 (m, 2H), 6.96 (t, J = 7.4 Hz, 1H), 4.05 (t, J = 8.2 Hz, 2H), 3.73 (t, J = 6.6 Hz, 2H), 3.62 (s, 3H), 3.12 (t, J = 8.4 Hz, 2H), 2.83 (t, J = 6.6 Hz, 2H), 2.19 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 207.2, 158.7, 143.4, 131.2, 127.2, 124.6, 122.9, 116.0, 60.1, 49.5, 43.5, 40.4, 30.4, 28.5; IR (KBr) υ 2927, 1712, 1656, 1598, 1481, 1396, 1371, 1262, 1166, 1033, 976, 860, 754 cm^{-1}; HRMS (Orbitrap, ESI) m/z calcd for $C_{14}H_{19}N_2O_3$ $[M + H]^+$ 263.1396, found 263.1382.

2-Methoxy-1-(2-oxopropyl)-5,6-dihydro-1*H*-pyrrolo[3,2,1-ij]-quinazolin-3(2*H*)-one (3fa). White sticky oil; 8.0 mg (10%); ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.07 (d, J = 7.4 Hz, 1H), 7.03 (t, J = 7.6 Hz, 1H), 6.88 (t, J = 7.5 Hz, 1H), 5.38 (dd, J = 7.4, 4.3 Hz, 1H), 4.06–4.03 (m, 2H), 3.74 (s, 3H), 3.26–3.14 (m, 3H), 2.67 (dd, J = 16.7, 7.4 Hz, 1H), 2.13 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 206.0, 153.5, 139.3, 128.0, 124.3, 123.8, 122.9, 118.3, 62.4, 57.1, 46.9, 46.0, 30.9, 28.1; IR (KBr) υ 2924, 1713, 1692, 1667, 1600, 1451, 1389, 1282, 1140, 1092, 997, 850 cm^{-1}; HRMS (Orbitrap, ESI) m/z calcd for $C_{14}H_{17}N_2O_3$ $[M + H]^+$ 261.1239, found 261.1227.

4-(1-Acetyl-4-methylindolin-7-yl)butan-2-one (3g). Brown solid; 65.0 mg (88%); mp 51–53 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 6.94 (d, J = 7.8 Hz, 1H), 6.86 (d, J = 7.8 Hz, 1H), 4.05 (t, J = 7.2 Hz, 2H), 2.91 (t, J = 7.4 Hz, 2H), 2.86 (t, J = 7.2 Hz, 2H), 2.77 (t, J = 7.7 Hz, 2H), 2.26 (s, 3H), 2.20 (s, 3H), 2.12 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 209.0, 168.8, 140.4, 133.4, 131.5, 128.8, 128.4, 126.6, 50.9, 43.8, 29.8, 28.6, 27.7, 23.8, 18.3; IR (KBr) υ 2920, 1707, 1658, 1582, 1410, 1379, 1350, 1257, 1161, 1110, 1010, 903, 804, 734 cm^{-1}; HRMS (Orbitrap, ESI) m/z calcd for $C_{15}H_{20}NO_2$ $[M + H]^+$ 246.1494, found 246.1482.

4-(1-Acetyl-5-bromoindolin-7-yl)butan-2-one (3h). Light brown solid; 90.0 mg (97%); mp 91–93 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.18 (s, 1H), 7.15 (s, 1H), 4.04 (t, J = 7.5 Hz, 2H), 2.99 (t, J = 7.5 Hz, 2H), 2.85–2.77 (m, 4H), 2.62 (s, 3H), 2.14 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 208.2, 168.9, 140.2, 137.0, 133.7, 131.1, 125.4, 118.3, 51.2, 43.3, 29.9, 29.8, 27.5, 23.8; IR (KBr) υ 2921, 1711, 1662, 1584, 1455, 1416, 1379, 1349, 1231, 1188, 1162, 1087, 920, 860, 794 cm^{-1}; HRMS (Orbitrap, ESI) m/z calcd for $C_{14}H_{17}BrNO_2$ $[M + H]^+$ 310.0443, found 310.0432.

4-(1-Acetyl-5-chloroindolin-7-yl)butan-2-one (3i). Light brown solid; 75.0 mg (94%); mp 81–83 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.02 (s, 1H), 6.99 (s, 1H), 4.04 (t, J = 7.5 Hz, 2H), 2.98 (t, J = 7.5 Hz, 2H), 2.85–2.76 (m, 4H), 2.25 (s, 3H), 2.13 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 208.2, 168.9, 139.6, 136.6, 133.3, 130.5, 128.2, 122.4, 51.2, 43.3, 29.9, 29.8, 27.6, 23.8; IR (KBr) υ 2923, 1709, 1661, 1588, 1421, 1381, 1352, 1232, 1187, 1017, 920, 861, 734 cm^{-1}; HRMS (Orbitrap, ESI) m/z calcd for $C_{14}H_{17}ClNO_2$ $[M + H]^+$ 266.0948, found 266.0933.

4-(1-Acetyl-6-fluoroindolin-7-yl)butan-2-one (3j). Light brown solid; 71.7 mg (96%); mp 80–85 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.01–6.98 (m, 1H), 6.78–6.75 (m, 1H), 4.06 (t, J = 7.5 Hz, 2H), 2.96 (t, J = 7.5 Hz, 2H), 2.91 (t, J = 7.0 Hz, 2H), 2.80 (t, J = 7.4 Hz, 2H), 2.26 (s, 3H), 2.14 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 208.8, 169.1, 161.5 (d, J_{C-F} = 240.2 Hz), 142.4 (d, J_{C-F} = 8.4 Hz), 130.0, 122.5 (d, J_{C-F} = 10.4 Hz), 122.2 (d, J_{C-F} = 19.2 Hz), 111.7 (d, J_{C-F} = 24.2 Hz), 51.9, 42.2, 29.6, 29.4, 23.8, 22.1; IR (KBr) υ 2918, 1711, 1666, 1594, 1473, 1432, 1385, 1354, 1275, 1232, 1185, 1117,

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1024, 963, 811 cm^{-1}; HRMS (Orbitrap, ESI) m/z calcd for $C_{14}H_{17}FNO_2$ $[M + H]^+$ 250.1243, found 250.1230.

4-(1-Acetyl-6-chloroindolin-7-yl)butan-2-one (3k). White solid; 29.5 mg (37%); mp 84−87 °C; ^1H NMR (700 MHz, CD_3OD) δ 7.19 (d, J = 7.9 Hz, 1H), 7.14 (d, J = 7.9 Hz, 1H), 4.15 (t, J = 7.3 Hz, 2H), 3.01 (t, J = 6.7 Hz, 2H), 3.96−2.80 (m, 4H), 2.32 (s, 3H), 2.15 (s, 3H); ^{13}C NMR (175 MHz, CD_3OD) δ 211.5, 172.2, 144.0, 136.4, 134.6, 131.5, 128.0, 124.6, 53.5, 42.4, 30.7, 29.7, 26.8, 23.8; IR (KBr) υ 2922, 1708, 1661, 1587, 1444, 1425, 1383, 1354, 1236, 1164, 1105, 1021, 935, 808, 734 cm^{-1}; HRMS (Orbitrap, ESI) m/z calcd for $C_{14}H_{17}ClNO_2$ $[M + H]^+$ 266.0948, found 266.0939.

4-(1-Acetyl-2-methylindolin-7-yl)butan-2-one (3l). Yellow sticky oil; 60.0 mg (82%); ^1H NMR (700 MHz, CD_3OD) δ 7.13 (d, J = 6.8 Hz, 1H), 7.11−7.07 (m, 2H), 4.69 (br s, 1H), 3.43−3.40 (m, 1H), 3.03−2.97 (m, 1H), 2.82−2.77 (m, 2H), 2.73−2.68 (m, 1H), 2.54 (d, J = 15.4 Hz, 1H), 2.32 (s, 3H), 2.11 (s, 3H), 1.24 (d, J = 6.6 Hz, 3H); ^{13}C NMR (175 MHz, CD_3OD) δ 211.3, 171.1, 140.3, 135.0, 133.8, 129.6, 127.1, 124.2, 59.8, 44.0, 37.8, 29.9, 29.3, 23.1, 20.6; IR (KBr) υ 2925, 1709, 1659, 1590, 1445, 1385, 1352, 1266, 1160, 1032, 994, 917, 771, 746 cm^{-1}; HRMS (Orbitrap, ESI) m/z calcd for $C_{15}H_{20}NO_2$ $[M + H]^+$ 246.1494, found 246.1480.

4-(1-Acetyl-5-methoxy-2-methylindolin-7-yl)butan-2-one (3m). Light brown sticky oil; 78.7 mg (95%); ^1H NMR (700 MHz, CD_3OD) δ 6.74 (s, 1H), 6.63 (s, 1H), 4.66 (s, 1H), 3.78 (s, 3H), 3.40−3.37 (m, 1H), 3.00 (br s, 1H), 2.81−2.69 (m, 3H), 2.49 (d, J = 15.4 Hz, 1H), 2.29 (s, 3H), 2.11 (s, 3H), 1.23 (d, J = 6.4 Hz, 3H); ^{13}C NMR (175 MHz, CD_3OD) δ 209.8, 169.3, 158.3, 135.7, 133.3, 132.1, 113.1, 108.5, 58.5, 54.5, 42.5, 36.5, 28.3, 28.0, 21.5, 19.0; IR (KBr) υ 2927, 1712, 1657, 1611, 1479, 1438, 1388, 1333, 1291, 1263, 1144, 1113, 1087, 1034, 994, 942, 864, 844 cm^{-1}; HRMS (Orbitrap, ESI) m/z calcd for $C_{16}H_{22}NO_3$ $[M + H]^+$ 276.1600, found 276.1592.

4-(1-Acetyl-5-fluoro-2-methylindolin-7-yl)butan-2-one (3n). Brown sticky oil; 57.9 mg (73%); ^1H NMR (700 MHz, CD_3OD) δ 6.89 (d, J = 7.5 Hz, 1H), 6.83 (d, J = 10.2 Hz, 1H), 4.71 (br s, 1H), 3.44−3.40 (m, 1H), 2.97−2.93 (m, 1H), 2.85−2.80 (m, 1H), 2.79−2.70 (m, 2H), 2.54 (d, J = 15.7 Hz, 1H), 2.31 (s, 3H), 2.12 (s, 3H), 2.15 (d, J = 6.5 Hz, 3H); ^{13}C NMR (175 MHz, CD_3OD) δ 209.3, 169.6, 160.2 (d, J_{C-F} = 240.6 Hz), 136.5 (d, J_{C-F} = 8.6 Hz), 135.0, 134.3, 114.0 (d, J_{C-F} = 22.9 Hz), 109.6 (d, J_{C-F} = 23.9 Hz), 58.7, 42.1, 36.4, 28.3, 27.6, 21.5, 19.0; IR (KBr) υ 2926, 1711, 1660, 1615, 1599, 1471, 1434, 1384, 1331, 1273, 1202, 1161, 1128, 1106, 1032, 970, 867, 729 cm^{-1}; HRMS (Orbitrap, ESI) m/z calcd for $C_{15}H_{19}FNO_2$ $[M + H]^+$ 264.1400, found 264.1386.

4-(1-Acetyl-5-chloro-2-methylindolin-7-yl)butan-2-one (3o). Light brown sticky oil; 69.3 mg (83%); ^1H NMR (700 MHz, CD_3OD) δ 7.14 (s, 1H), 7.10 (s, 1H), 4.70 (t, J = 6.5 Hz, 1H), 3.43−3.40 (m, 1H), 2.97−2.92 (m, 1H), 2.85−2.79 (m, 1H), 2.77−2.69 (m, 2H), 2.54 (d, J = 15.7 Hz, 1H), 2.31 (s, 3H), 2.12 (s, 3H), 1.25 (d, J = 6.5 Hz, 3H); ^{13}C NMR (175 MHz, CD_3OD) δ 209.3, 169.7, 137.8, 136.4, 134.1, 130.5, 127.8, 122.7, 58.5, 42.1, 36.1, 28.3, 27.5, 21.6, 19.1; IR (KBr) υ 2927, 1714, 1665, 1589, 1455, 1421, 1380, 1349, 1334, 1298, 1161, 1117, 1087, 1033, 995, 904, 850, 735 cm^{-1}; HRMS (Orbitrap, ESI) m/z calcd for $C_{15}H_{19}ClNO_2$ $[M + H]^+$ 280.1104, found 280.1094.

4-(1-Acetyl-3-methylindolin-7-yl)butan-2-one (3p). Yellow sticky oil; 62.0 mg (84%); ^1H NMR (500 MHz, $CDCl_3$) δ 7.09−7.01 (m, 3H), 4.19 (br s, 1H), 3.55 (t, J = 7.5 Hz, 1H), 3.35−3.28 (m, 1H), 2.94−2.78 (m, 4H), 2.26 (s, 3H), 2.13 (s, 3H), 1.26 (d, J = 6.8 Hz, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 208.9, 168.8, 140.5, 139.9, 131.7, 128.5, 125.7, 120.9, 58.9, 43.6, 36.4, 29.7, 27.7, 23.8, 17.9; IR (KBr) υ 2961, 1707, 1645, 1590, 1443, 1387, 1352, 1224, 1161, 1032, 947, 893, 781 cm^{-1}; HRMS (Orbitrap, ESI) m/z calcd for $C_{15}H_{20}NO_2$ $[M + H]^+$ 246.1494, found 246.1480.

4-(1-Acetyl-3,3-dimethyl-2-phenylindolin-7-yl)butan-2-one (3q). White sticky oil; 71.1 mg (71%); ^1H NMR (700 MHz, CD_3OD) δ 7.28−7.26 (m, 3H), 7.19−7.16 (m, 2H), 7.06−7.04 (m, 2H), 7.02 (dd, J = 6.4, 2.1 Hz, 1H), 5.13 (s, 1H), 3.04−2.83 (m, 4H), 2.24 (s, 3H), 2.15 (s, 3H), 1.42 (s, 3H), 0.94 (s, 3H); ^{13}C NMR (175 MHz, CD_3OD) δ 209.7, 170.5, 142.9, 140.1, 138.8, 131.0, 128.4, 128.1, 127.6, 126.6, 126.1, 120.1, 77.4, 45.9, 42.2, 30.2, 28.4, 27.5, 22.1, 21.1; IR (KBr) υ 2959, 1713, 1667, 1590, 1440, 1382, 1343, 1297, 1246, 1160, 1031, 934, 837, 781, 754 cm^{-1}; HRMS (Orbitrap, ESI) m/z calcd for $C_{22}H_{26}NO_2$ $[M + H]^+$ 336.1964, found 336.1951.

4-(9-Acetyl-4a-methyl-3,4,4a,9-tetrahydro-2*H*-carbazol-8-yl)butan-2-one (3r). Yellow sticky oil; 45.6 mg (51%); ^1H NMR (700 MHz, CD_3OD) δ 7.13 (t, J = 7.5 Hz, 1H), 7.08 (dd, J = 7.7, 1.1 Hz, 1H), 7.04 (dd, J = 7.2, 1.1 Hz, 1H), 5.69 (t, J = 3.5 Hz, 1H), 2.99−2.89 (m, 2H), 2.84−2.74 (m, 2H), 2.39−2.34 (m, 4H), 2.23−2.16 (m, 2H), 2.13 (s, 3H), 2.00−1.93 (m, 1H), 1.91−1.87 (m, 1H), 1.47 (td, J = 14.7, 3.4 Hz, 1H), 1.26 (s, 3H); ^{13}C NMR (175 MHz, CD_3OD) δ 210.0, 171.1, 148.3, 142.8, 139.8, 131.6, 127.8, 126.0, 118.8, 115.3, 42.8, 42.1, 31.1, 28.4, 27.4, 24.1, 23.4, 21.6, 18.0; IR (KBr) υ 2936, 1709, 1671, 1595, 1433, 1366, 1329, 1290, 1256, 1160, 1012, 935, 893, 787, 750 cm^{-1}; HRMS (Orbitrap, ESI) m/z calcd for $C_{19}H_{24}NO_2$ $[M + H]^+$ 298.1807, found 298.1791.

Methyl 1-Acetyl-7-(3-oxobutyl)indoline-5-carboxylate (3s). Pale yellow sticky oil; 52.9 mg (61%); ^1H NMR (500 MHz, $CDCl_3$) δ 7.75 (s, 1H), 7.71 (s, 1H), 4.09 (t, J = 7.5 Hz, 2H), 3.87 (s, 3H), 2.05 (t, J = 7.5 Hz, 2H), 2.89−2.82 (m, 4H), 2.28 (s, 3H), 2.14 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 208.3, 169.0, 166.7, 144.9, 135.0, 131.3, 130.6, 127.1, 123.5, 52.0, 51.2, 43.3, 29.8, 29.4, 27.7, 23.9; IR (KBr) υ 2923, 1711, 1669, 1433, 1382, 1293, 1208, 1008, 771 cm^{-1}; HRMS (quadrupole, FAB) m/z calcd for $C_{16}H_{20}NO_4$ $[M + H]^+$ 290.1392, found 290.1400.

3-(1-Acetylindolin-7-yl)propanal (4b). Brown sticky oil; 40.4 mg (62%); ^1H NMR (500 MHz, $CDCl_3$) δ 9.76 (t, J = 1.6 Hz, 1H), 7.09−7.02 (m, 3H), 4.05 (t, J = 7.5 Hz, 2H), 3.03−2.98 (m, 4H), 2.77−2.76 (m, 2H), 2.28 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 202.5, 168.8, 140.8, 134.9, 131.1, 128.4, 125.6, 122.5, 51.2, 43.6, 29.9, 26.4, 23.9; IR (KBr) υ 2936, 1709, 1671, 1595, 1433, 1366, 1290, 1256, 1160, 1012, 935, 893, 787 cm^{-1}; HRMS (Orbitrap, ESI) m/z calcd for $C_{13}H_{16}NO_2$ $[M + H]^+$ 218.1181, found 218.1174.

1-(1-Acetylindolin-7-yl)pentan-3-one (4c). Light brown sticky oil; 56.0 mg (77%); ^1H NMR (500 MHz, CD_3OD) δ 7.13−7.05 (m, 3H), 4.13 (t, J = 7.4 Hz, 2H), 3.03 (t, J = 7.4 Hz, 2H), 2.88 (t, J = 7.2 Hz, 2H), 2.74 (t, J = 8.1 Hz, 2H), 2.44 (q, J = 7.3 Hz, 2H), 2.31 (s, 3H), 0.99 (t, J = 7.3 Hz, 3H); ^{13}C NMR (125 MHz, CD_3OD) δ 212.4, 170.0, 140.3, 135.4, 131.7, 128.0, 125.5, 122.0, 51.3, 41.4, 35.0, 29.3, 27.8, 22.3, 6.6; IR (KBr) υ 2936, 1707, 1659, 1590, 1448, 1383, 1351, 1331, 1236, 1188, 1111, 1016, 919, 848, 778, 754 cm^{-1}; HRMS (Orbitrap, ESI) m/z calcd for $C_{15}H_{20}NO_2$ $[M + H]^+$ 246.1494, found 246.1479.

1-(1-Acetylindolin-7-yl)undecan-3-one (4d). Light brown sticky oil; 56.0 mg (57%); ^1H NMR (700 MHz, CD_3OD) δ 7.08 (d, J = 7.0 Hz, 1H), 7.05−7.01 (m, 2H), 4.09 (t, J = 7.3 Hz, 2H), 3.00 (t, J = 7.3 Hz, 2H), 2.86 (t, J = 7.3 Hz, 2H), 2.70 (t, J = 7.9 Hz, 2H), 2.38 (t, J = 7.2 Hz, 2H), 2.28 (s, 3H), 1.50−1.46 (m, 2H), 1.31−1.21 (m, 10H), 0.88 (t, J = 7.0 Hz, 3H); ^{13}C NMR (175 MHz, CD_3OD) δ 213.7, 171.5, 141.9, 136.9, 133.3, 129.6, 127.0, 123.6, 52.8, 43.6, 43.3, 33.1, 30.9, 30.6, 30.5, 30.4, 29.4, 25.0, 23.8, 14.5; IR (KBr) υ 2924, 1709, 1666, 1592, 1449, 1384, 1350, 1216, 1188, 1122, 1002, 978, 919, 849, 758 cm^{-1}; HRMS (Orbitrap, ESI) m/z calcd for $C_{21}H_{32}NO_2$ $[M + H]^+$ 330.2433, found 330.2417.

1-(1-Acetylindolin-7-yl)-5-phenylpentan-3-one (4e). Yellow sticky oil; 60.0 mg (62%); ^1H NMR (500 MHz, $CDCl_3$) δ 7.30−7.27 (m, 2H), 7.22−7.18 (m, 3H), 7.10−7.02 (m, 3H), 4.06 (t, J = 7.4 Hz, 2H), 3.03 (t, J = 7.6 Hz, 2H), 2.94−2.88 (m, 4H), 2.81−2.74 (m, 4H), 2.29 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 209.8, 168.8, 141.2, 140.8, 134.8, 131.7, 128.5, 128.4, 128.3, 126.0, 125.5, 122.3, 51.2, 44.1, 42.8, 30.0, 29.7, 27.8, 23.8; IR (KBr) υ 2924, 1707, 1659, 1590, 1448, 1383, 1352, 1235, 1186, 1094, 973, 919, 847, 780 cm^{-1}; HRMS (Orbitrap, ESI) m/z calcd for $C_{21}H_{24}NO_2$ $[M + H]^+$ 322.1807, found 322.1796.

3-(1-Acetylindolin-7-yl)-1-cyclohexylpropan-1-one (4f). Light brown sticky oil; 54.1 mg (60%); ^1H NMR (500 MHz, $CDCl_3$) δ 7.06−7.00 (m, 3H), 4.04 (t, J = 7.2 Hz, 2H), 2.99 (t, J = 7.4 Hz, 2H), 2.88−2.85 (m, 2H), 1.65−1.61 (m, 1H), 1.34−1.12 (m, 5H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 213.8, 168.8, 140.9, 134.7, 132.1, 118.4, 125.4, 122.1, 51.2, 50.7, 40.4, 30.0, 28.4, 27.6, 25.8, 25.7, 23.8; IR (KBr) υ 2927, 1703, 1655, 1482, 1448, 1401, 1340, 1320, 1260, 1187,

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1089, 1029, 922, 851, 753 cm^{-1}; HRMS (Orbitrap, ESI) m/z calcd for $C_{19}H_{26}NO_2$ $[M + H]^+$ 300.1964, found 300.1955.

3-(1-Acetylindolin-7-yl)-1-(cyclohex-3-enyl)propan-1-one (4g). Yellow sticky oil; 38.6 mg (43%); ^1H NMR (500 MHz, $CDCl_3$) δ 7.07−7.02 (m, 3H), 5.67 (s, 2H), 4.05 (t, J = 7.3 Hz, 2H), 3.01 (t, J = 7.4 Hz, 2H), 2.92−2.80 (m, 4H), 2.63−2.57 (m, 1H), 2.27 (s, 3H), 2.20−2.13 (m, 2H), 2.11−2.00 (m, 2H), 1.93−1.89 (m, 1H), 1.58−1.50 (m, 1H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 213.3, 168.9, 140.9, 134.8, 132.1, 128.5, 126.6, 125.5, 122.2, 51.2, 46.6, 40.6, 30.0, 27.7, 26.8, 24.7, 24.6, 23.8; IR (KBr) υ 2923, 1704, 1656, 1593, 1482, 1448, 1385, 1354, 1294, 1259, 1188, 1018, 921, 849, 753 cm^{-1}; HRMS (Orbitrap, ESI) m/z calcd for $C_{19}H_{24}NO_2$ $[M + H]^+$ 298.1807, found 298.1797.

4-(1-Acetylindolin-7-yl)-1-(benzyloxy)butan-2-one (4h). Light brown sticky oil; 21.2 mg (21%); ^1H NMR (500 MHz, $CDCl_3$) δ 7.36−7.28 (m, 5H), 7.07−7.01 (m, 3H), 4.55 (s, 2H), 4.06 (s, 2H), 4.03 (t, J = 7.4 Hz, 2H), 3.00 (t, J = 7.4 Hz, 2H), 2.92 (t, J = 6.8 Hz, 2H), 2.82 (t, J = 7.8 Hz, 2H), 2.25 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 208.4, 168.8, 140.8, 137.3, 134.8, 131.5, 128.5, 128.4, 128.0, 127.9, 125.5, 122.3, 74.9, 73.3, 51.1, 38.9, 29.9, 27.5, 23.8; IR (KBr) υ 2923, 1715, 1660, 1590, 1449, 1384, 1353, 1220, 1091, 918, 849, 778 cm^{-1}; HRMS (Orbitrap, ESI) m/z calcd for $C_{21}H_{24}NO_3$ $[M + H]^+$ 338.1756, found 338.1748.

4-(9-(Pyrimidin-2-yl)-9*H*-carbazol-1-yl)butan-2-one (6b). Brown sticky solid; 39.7 mg (42%); ^1H NMR (700 MHz, $CDCl_3$) δ 8.88 (d, J = 4.9 Hz, 2H), 8.08 (d, J = 7.7 Hz, 1H), 8.04 (d, J = 7.5 Hz, 1H), 8.01 (d, J = 7.5 Hz, 1H), 7.45 (dt, J = 7.7, 1.1 Hz, 1H), 7.38−7.30 (m, 3H), 7.28−7.27 (m, 1H), 2.92 (t, J = 7.7 Hz, 2H), 2.65 (t, J = 8.1 Hz, 2H), 2.00 (s, 3H); ^{13}C NMR (175 MHz, $CDCl_3$) δ 207.8, 158.8, 158.6, 141.4, 138.1, 128.2, 126.9, 126.8, 126.6, 125.4, 122.4, 122.1, 119.9, 118.3, 118.2, 112.2, 43.1, 29.8, 28.0; IR (KBr) υ 2923, 1709, 1560, 1452, 1408, 1335, 1212, 1159, 1021, 933, 879, 753 cm^{-1}; HRMS (Orbitrap, ESI) m/z calcd for $C_{20}H_{18}N_3O$ $[M + H]^+$ 316.1435, found 316.1450.

4,4′-(1-(Pyrimidin-2-yl)-1*H*-pyrrole-2,5-diyl)dibutan-2-one (6c). Brown sticky solid; 47.1 mg (55%); ^1H NMR (500 MHz, $CDCl_3$) δ 8.76 (d, J = 4.8 Hz, 2H), 7.22 (t, J = 4.8 Hz, 1H), 5.92 (s, 2H), 2.96 (t, J = 7.3 Hz, 4H), 2.72 (t, J = 8.0 Hz, 4H), 2.10 (s, 6H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 208.2, 158.4, 157.8, 133.2, 118.4, 107.8, 43.5, 29.9, 22.1; IR (KBr) υ 2923, 1710, 1560, 1521, 1425, 1359, 1256, 1162, 1093, 1021, 947, 818, 768 cm^{-1}; HRMS (Orbitrap, ESI) m/z calcd for $C_{16}H_{20}N_3O_2$ $[M + H]^+$ 286.1556, found 286.1543.

4,4′-(3-Methyl-1-(pyrimidin-2-yl)-1*H*-pyrrole-2,5-diyl)-dibutan-2-one (6d). Brown sticky oil; 43.0 mg (49%); ^1H NMR (500 MHz, $CDCl_3$) δ 8.72 (d, J = 4.3 Hz, 2H), 7.18 (t, J = 4.8 Hz, 1H), 5.81 (s, 1H), 2.96−2.89 (m, 4H), 2.71 (t, J = 8.0 Hz, 2H), 2.62 (t, J = 8.0 Hz, 2H), 2.11 (s, 3H), 2.05 (s, 3H), 2.01 (s, 3H); ^{13}C NMR (155 MHz, $CDCl_3$) δ 208.7, 208.3, 158.3, 157.8, 132.0, 128.5, 118.1, 117.1, 110.7, 44.1, 43.6, 29.9, 22.1, 19.8, 11.0; IR (KBr) υ 2923, 1706, 1561, 1423, 1360, 1160, 1026, 949, 799, 747 cm^{-1}; HRMS (Orbitrap, ESI) m/z calcd for $C_{17}H_{22}N_3O_2$ $[M + H]^+$ 300.1712, found 300.1699.

Experimental Procedure for the Oxidation of 7-Alkylated Indoline. To a stirred solution of **3a** (69.4 mg, 0.3 mmol, 100 mol %) in DCE (1 mL) was added 2,3-dichloro-5,6-dicyano-1,4-benzoquinone (DDQ) (204.3 mg, 0.9 mmol, 300 mol %) at room temperature. The reaction mixture was allowed to stir at room temperature for 36 h. The reaction mixture was quenched with brine and partitioned between EtOAc and H_2O. The organic layer was dried over $MgSO_4$ and concentrated in vacuo. The residue was purified by flash column chromatography (silica gel, n-hexanes/EtOAc = 2:1) to afford 27.6 mg of **6e** in 40% yield.

4-(1-Acetyl-1*H*-indol-7-yl)butan-2-one (6e). Yellow sticky oil; 27.6 mg (40%); ^1H NMR (500 MHz, $CDCl_3$) δ 7.41−7.39 (m, 2H), 7.20 (t, J = 7.5 Hz, 1H), 7.15 (d, J = 7.0 Hz, 1H), 6.62 (d, J = 4.0 Hz, 1H), 3.26 (t, J = 7.5 Hz, 2H), 2.83 (t, J = 8.0 Hz, 2H), 2.66 (s, 3H), 2.14 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 208.7, 168.0, 134.2, 132.5, 129.7, 127.6, 126.8, 124.3, 119.1, 109.3, 45.4, 29.8, 29.7, 24.6; IR (KBr) υ 2922, 1713, 1550, 1454, 1362, 1306, 1205, 1059, 932, 792 cm^{-1}; HRMS (quadrupole, FAB) m/z calcd for $C_{14}H_{16}NO_2$ $[M + H]^+$ 230.1181, found 230.1177.

General Procedure for the Transformation of β-Indolinic Carbonyl Compounds. To an oven-dried sealed tube charged with **3a** (46.3 mg, 0.2 mmol, 100 mol %) in MeOH (1 mL) was added K_2CO_3 (42 mg, 0.3 mmol, 150 mol %) at room temperature. The reaction mixture was allowed to stir at 80 °C for 16 h. The reaction mixture was quenched with brine and partitioned between EtOAc and H_2O. The organic layer was dried over $MgSO_4$ and concentrated in vacuo. The residue was purified by flash column chromatography (silica gel, n-hexanes/EtOAc = 2:1) to afford 25.3 mg of **7a** in 59% yield.

1-(4-Methyl-2,6-dihydro-1*H*-pyrrolo[3,2,1-ij]quinolin-5-yl)-ethanone (7a). Dark brown sticky oil; 25.3 mg (59%); ^1H NMR (500 MHz, $CDCl_3$) δ 6.95−6.93 (m, 1H), 6.86−6.82 (m, 2H), 3.92 (t, J = 8.1 Hz, 2H), 3.85 (s, 2H), 3.14 (t, J = 8.0 Hz, 2H), 2.40 (s, 3H), 2.18 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 196.7, 149.8, 141.1, 128.1, 125.9, 123.5, 122.7, 119.4, 103.5, 47.9, 30.3, 28.7, 28.0, 17.3; IR (KBr) υ 2923, 1619, 1519, 1470, 1401, 1281, 1212, 1112, 1009, 940, 762 cm^{-1}; HRMS (quadrupole, EI) m/z calcd for $C_{14}H_{15}NO$ $[M]^+$ 213.1154, found 213.1153.

1-(2,4-Dimethyl-2,6-dihydro-1*H*-pyrrolo[3,2,1-ij]quinolin-5-yl)ethanone (7b). Yellow sticky oil; 17.0 mg (37%); ^1H NMR (500 MHz, $CDCl_3$) δ 6.95−6.92 (m, 1H), 6.88−6.84 (m, 2H), 4.49−4.42 (m, 1H), 3.86 (s, 2H), 3.38−3.33 (m, 1H), 2.68 (dd, J = 16.0, 2.0 Hz, 1H), 2.44 (s, 3H), 2.19 (s, 3H), 1.32 (d, J = 6.5 Hz, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 196.8, 149.3, 140.2, 126.8, 125.9, 123.7, 122.9, 119.6, 103.6, 55.4, 36.8, 30.4, 28.7, 22.3, 17.3; IR (KBr) υ 2923, 1706, 1644, 1599, 1463, 1393, 1275, 1221, 1174, 1121, 1000, 926 cm^{-1}; HRMS (quadrupole, EI) m/z calcd for $C_{15}H_{17}NO$ $[M]^+$ 227.1310, found 227.1307.

1-(1,4-Dimethyl-2,6-dihydro-1*H*-pyrrolo[3,2,1-ij]quinolin-5-yl)ethanone (7c). Yellow sticky oil; 26.5 mg (58%); ^1H NMR (500 MHz, $CDCl_3$) δ 6.93−6.91 (m, 1H), 6.87−6.86 (m, 2H), 4.10 (t, J = 9.0 Hz, 1H), 3.86 (s, 2H), 3.51−3.42 (m, 2H), 2.39 (s, 3H), 2.19 (s, 3H), 1.33 (d, J = 7.0 Hz, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 196.8, 149.7, 140.6, 133.2, 126.1, 123.6, 121.5, 119.3, 103.6, 56.2, 35.3, 30.3, 28.6, 20.1, 17.3; IR (KBr) υ 2924, 1711, 1614, 1579, 1514, 1459, 1395, 1281, 1220, 1135, 1044, 1011, 946 cm^{-1}; HRMS (quadrupole, EI) m/z calcd for $C_{15}H_{17}NO$ $[M]^+$ 227.1310, found 227.1305.

1-(4-Methyl-2,6-dihydro-1*H*-pyrrolo[3,2,1-ij]quinolin-5-yl)-propan-1-one (7d). Yellow solid; 23.0 mg (51%); mp 126−128 °C; ^1H NMR (500 MHz, $CDCl_3$) δ 6.94−6.93 (m, 1H), 6.85−6.81 (m, 2H), 3.91 (t, J = 8.0 Hz, 2H), 3.86 (s, 2H), 3.13 (t, J = 8.0 Hz, 2H), 2.45−2.41 (m, 5H), 1.09 (t, J = 7.0 Hz, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 199.6, 149.4, 141.2, 128.0, 125.9, 123.3, 122.6, 119.2, 102.9, 47.9, 34.2, 28.1, 28.0, 17.3, 8.6; IR (KBr) υ 2928, 1644, 1622, 1534, 1480, 1405, 1370, 1271, 1208, 1098, 1053, 927, 755 cm^{-1}; HRMS (quadrupole, EI) m/z calcd for $C_{15}H_{17}NO$ $[M]^+$ 227.1310, found 227.1307.

Experimental Procedure for the Reduction of a Tricyclic Indoline. To a stirred solution of **7a** (42.7 mg, 0.2 mmol, 100 mol %) in MeOH (1 mL) was added 10% Pd/C (21 mg, 0.02 mmol, 10 mol %). The reaction mixture was stirred under a hydrogen balloon for 12 h and concentrated in vacuo. The residue was purified by flash column chromatography (silica gel, n-hexanes/EtOAc = 7:1) to afford 30.1 mg of **8a** in 70% yield.

1-(4*S*′,5*S*′)-4-Methyl-2,4,5,6-tetrahydro-1*H*-pyrrolo[3,2,1-ij]-quinolin-5-yl)ethanone (8a). Brown sticky oil; 30.1 mg (70%); ^1H NMR (500 MHz, $CDCl_3$) δ 6.94 (d, J = 7.5 Hz, 1H), 6.87 (d, J = 7.5 Hz, 1H), 6.32 (t, J = 7.5 Hz, 1H), 3.75−3.71 (m, 1H), 3.47−3.41 (m, 1H), 3.31−3.27 (m, 1H), 3.11−3.07 (m, 1H), 3.02−2.92 (m, 3H), 2.78 (dd, J = 17.0, 5.5 Hz, 1H), 2.23 (s, 3H), 0.94 (d, J = 6.5 Hz, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 208.9, 147.7, 128.5, 126.2, 122.2, 118.2, 116.7, 52.4, 50.6, 50.4, 28.9, 28.8, 23.0, 11.3; IR (KBr) υ 2921, 1705, 1600, 1483, 1459, 1435, 1360, 1337, 1271, 1219, 1160, 1106, 1050, 949, 751 cm^{-1}; HRMS (Orbitrap, ESI) m/z calcd for $C_{14}H_{18}NO$ $[M + H]^+$ 216.1388, found 216.1380.

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■ ASSOCIATED CONTENT

Supporting Information

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Optimization table and spectroscopic data for all compounds (PDF)

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Notes

The authors declare no competing financial interest.

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