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Cycloaromatization Approach to Polysubstituted Indolizines from 2-Acetylpyrroles: Decoration of the Pyridine Unit

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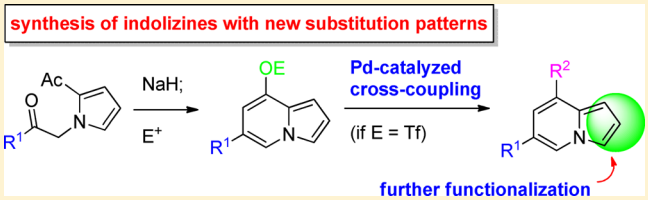
Supporting Information

ABSTRACT: A new synthetic route to indolizines with various substituents on the pyridine moiety was developed by utilizing a facile cycloaromatization of 2-acetylpyrrole derivatives. Without isolation, the resulting intermediates were allowed to react with various electrophiles to afford a range of indolizines. In particular, Suzuki–Miyaura cross-coupling of *O*-triflates with (hetero)arylboronic acids permitted introduction of diverse substituents at the C8 position of an indolizine skeleton.



Strategic introduction of functional substituents at various positions of core chemical skeletons at will is very important in medicinal chemistry with respect to drug discovery. For instance, as illustrated in Figure 1, several indolizines were reported to exhibit different biological activities with therapeutic potential depending on the substitution patterns of the core structure.[1] Therefore, development of new synthetic methods to install diverse functional groups at suitable positions around an indolizine[2] core should further extend versatility of this scaffold in many different medicinal areas.

In contrast to most synthetic approaches toward this skeleton where pyrrole rings were formed from pyridines (from **1** to **2**, Scheme 1),[3] construction of pyridine rings from pyrroles has been rare (from **3** to **1**).[4]

As part of our research interest on nitrogen-fused bicycles, we have recently reported mild and facile syntheses of indolizines and indolizinones, employing a strategy where activation of alkene or alkyne allows for subsequent intramolecular ring closure by nucleophilic attack of a tethered pyridine in a highly efficient manner.[5] While these approaches enable us to easily decorate the pyrrole ring with various functional groups, we also hope to design new methods to gain access to indolizines with diverse functionalities incorporated on the pyridine moiety. In this context, here we report a novel synthesis of indolizines from 2-acetylpyrrole based on a facile cycloaromatization strategy.[6]

As outlined in Scheme 2, we reasoned that **4** would undergo intramolecular aldol-type cyclization in the presence of base followed by tautomerization to afford **5**, which can be trapped with various electrophiles to give 6,8-disubstituted indolizines **6**. To the best of our knowledge, indolizines with this type of substitution have not been disclosed yet.

To test this idea, **4a** was used as a substrate for optimization study.[7] When **4a** was treated with NaH (2.5 equiv) in THF at room temperature, the presumed 8-hydroxyindolizine was detected on TLC. Without isolation of this intermediate, acetic anhydride was added to the reaction mixture, which resulted in 8-acetoxyindolizine **6a** in 90% yield (Table 1, entry 1). Subsequent treatment of the cyclized intermediate with tosyl chloride gave the corresponding *O*-tosylate **6b** (entry 2).

Since (hetero)aryl *O*-triflates are valuable substrates for a number of metal-catalyzed cross-coupling reactions, we decided to prepare the *O*-triflate from this reaction. Thus, the intermediate was allowed to react with *N*-phenyl-bis(trifluoromethanesulfonimide) to provide **6c** in an excellent yield (entry 3). Similarly, the intermediates derived from **4b** and **4c** were isolated as *O*-acetates, *O*-tosylates, and *O*-triflates in good yields (entries 4–9).

In the mean time, similar efforts with substrate **4d** were attempted (Scheme 3). In this case, the intermediate formed by base-mediated intramolecular Claisen-type cyclization was isolated as bis-*O*-acetates **6j** or bis-*O*-mesylates **6k** upon subsequent exposure to acetic anhydride or mesyl chloride, respectively.

Having secured a facile sequential one-pot route to functionalized indolizines in hand, we next directed our attention to Pd-catalyzed Suzuki–Miyaura coupling reactions of *O*-triflates, **6c** and **6f**. After brief screening of the reaction conditions, we found that the reaction of **6c** with 4-acetylphenylboronic acid (1.5 equiv) in the presence of $Pd(PPh_3)_4$ (5 mol %) and K_3PO_4 (3 equiv)[8] in THF at 90 °C afforded the coupled product **7a** in 69% yield (Table 2, entry 1).[9] Under these conditions, several boronic acids were successfully employed to furnish the corresponding coupled products in good yields. In the case of 4-pyridineboronic acid, higher reaction temperature and use of 1,4-dioxane as solvent were required (entry 5).

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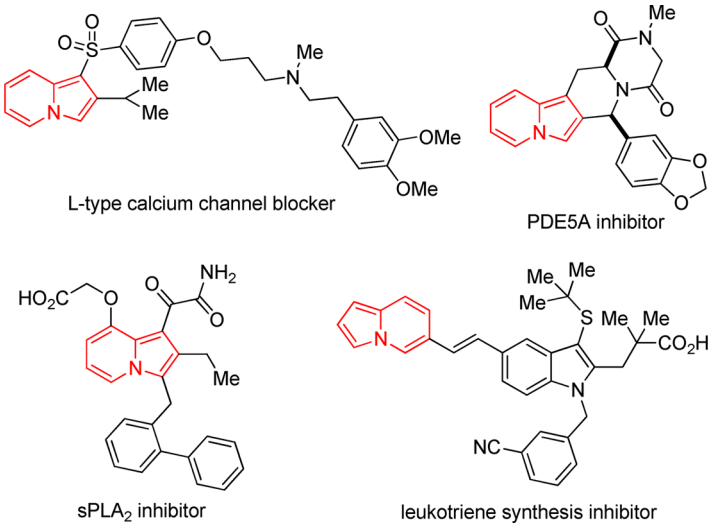
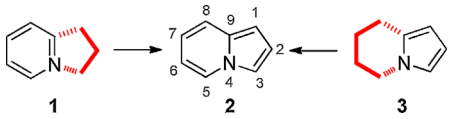


Figure 1. Some representative biological modulators containing an indolizine core.

Scheme 1. Two Approaches to the Indolizine Scaffold



Scheme 2. Synthesis of 6,8-Disubstituted Indolizines

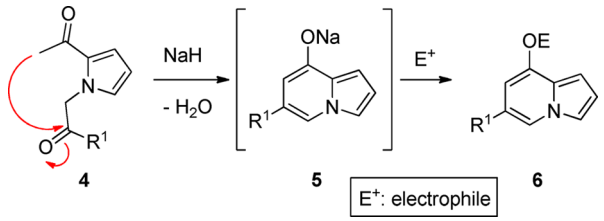
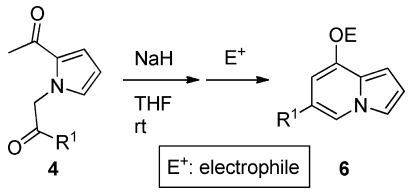


Table 1. Cycloaromatization of 4 Followed by Reactions with Electrophiles[a]

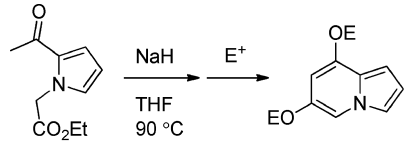


entry	4	electrophile	6	yield (%)[b]
1	**4a** (R^1 = Ph)	Ac_2O	**6a** (E = Ac)	90
2	**4a**	TsCl	**6b** (E = Ts)	92
3	**4a**	$PhNTf_2$	**6c** (E = Tf)	95
4	**4b** (R^1 = 4-MeOPh)	Ac_2O	**6d** (E = Ac)	97
5	**4b**	TsCl	**6e** (E = Ts)	89
6	**4b**	$PhNTf_2$	**6f** (E = Tf)	67
7	**4c** (R^1 = 4-ClPh)	Ac_2O	**6g** (E = Ac)	88
8	**4c**	TsCl	**6h** (E = Ts)	85
9	**4c**	$PhNTf_2$	**6i** (E = Tf)	74

[a]To a stirred solution of **4** (0.132 mmol) in THF (2 mL) was added 60% NaH (13.2 mg, 2.5 equiv) at 0 °C. After being stirred at rt for 1 h, the reaction mixture was treated with appropriate electrophile (1.5 equiv). [b]Isolated yields (%).

Notably, cross-coupled products from the reactions with boronic acids having electron-donating groups seemed to be unstable; in some cases, pure NMR data could not be obtained even after flash column chromatography due to rapid decomposition. For example, it was found that indolizine bearing 4-methoxyphenyl group at the C8 position initially

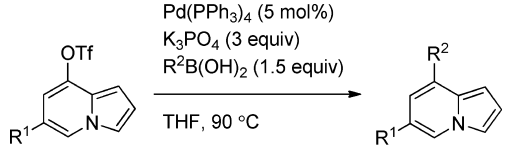
Scheme 3. Cycloaromatization of 4d Followed by Reactions with Electrophiles



4d

$E^+ = Ac_2O$: **6j** (E = Ac) (80%)
E^+ = MsCl: **6k** (E = Ms) (37%)

Table 2. Suzuki–Miyaura Reaction of 6[a]



6c or 6f **7a-l**

entry	6	$R^2B(OH)_2$	7	yield[b]
1	**6c**	4-acetylphenylboronic acid	**7a**	69
2	**6c**	3-acetylphenylboronic acid	**7b**	60
3	**6c**	5-acetylthiopheneboronic acid	**7c**	79
4	**6c**	3-cyanophenylboronic acid	**7d**	85
5[c]	**6c**	4-pyridineboronic acid	**7e**	42
6	**6c**	3-methoxycarbonylphenylboronic acid	**7f**	82
7	**6c**	4-methoxycarbonylphenylboronic acid	**7g**	59
8	**6c**	3-nitrophenylboronic acid	**7h**	65
9	**6c**	4-nitrophenylboronic acid	**7i**	88
10	**6f**	4-nitrophenylboronic acid	**7j**	82
11	**6f**	3-cyanophenylboronic acid	**7k**	40
12	**6f**	4-methoxycarbonylphenylboronic acid	**7l**	60

[a]A mixture of **6** (0.161 mmol), arylboronic acid (1.5 equiv), $Pd(PPh_3)_4$ (5 mol %), and K_3PO_4 (3 equiv) in THF (2 mL) was heated at 90 °C for 2 h unless otherwise noted. [b]Isolated yield (%) [c]1,4-Dioxane was used as solvent, and the reaction mixture was heated at 120 °C.

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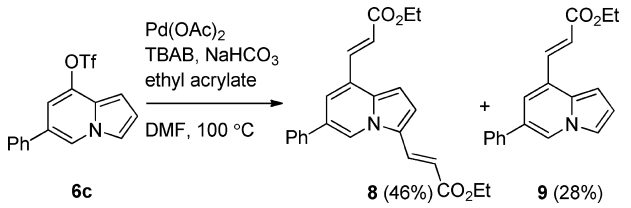
isolated in 82% yield was quickly decomposed to give impure NMR spectra (data not shown).

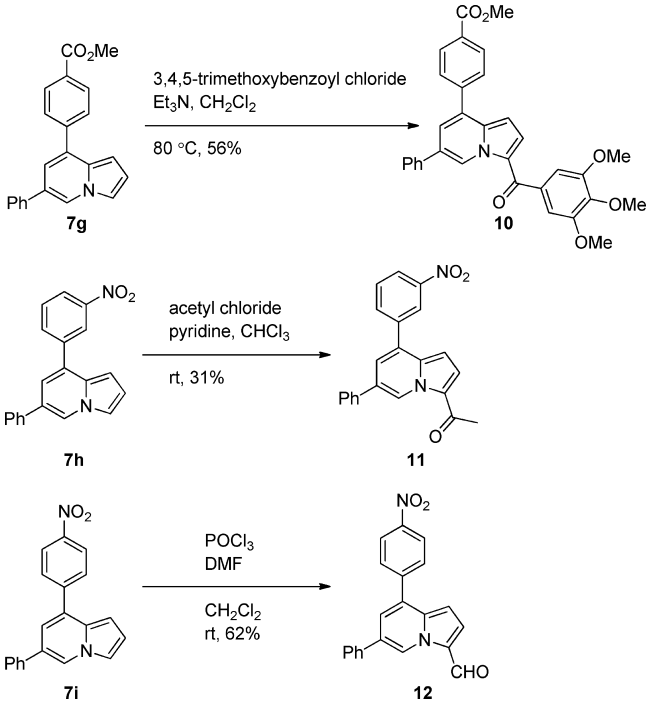
Heck coupling of **6c** with ethyl acrylate was also attempted under Jeffery's phosphine-free conditions[10] as shown in Scheme 4. When 4 equiv of ethyl acrylate was used, the expected product **9** was obtained along with **8**.[11]

Scheme 4. Heck Reaction of 6c



Finally, introduction of additional functional groups at the C3 site of the indolizines prepared by this route was demonstrated in Scheme 5, thereby increasing diversity of

Scheme 5. Further Elaboration of the Suzuki–Miyaura Products



this skeleton. For this purpose, Friedel–Crafts acylation of **7g** and **7h** with 3,4,5-trimethoxybenzoyl chloride and acetyl chloride was undertaken, delivering **10** and **11**, respectively (unoptimized yields).[12] Vilsmeier–Haack formylation[13] of indolizine **7i** proceeded to give **12** in 62% yield.[14]

In summary, we have described a novel synthetic approach to indolizines in which pyridine parts with unique substitution patterns were constructed from acetylpyrroles. In particular, the resulting *O*-triflates from a sequential one-pot cycloaromatization/O-sulfonylation process were employed in palladium-catalyzed Suzuki–Miyaura cross-coupling reactions, allowing easy access to indolizines with various substituents at the C6 and C8 positions. Subsequent elaboration of the resulting Suzuki–Miyaura products at the C3 position by additional functionalization was also demonstrated to maximize diversity. As new substitution patterns on the pyridine unit of an indolizine core were made possible, this chemistry should further extend the utility of this skeleton.

EXPERIMENTAL SECTION

General Procedure for the Synthesis of 4. A mixture of 2-acetylpyrrole (2.749 mmol), K_2CO_3 (6.873 mmol, 2.5 equiv), and 2-bromoacetophenone (3.024 mmol, 1.1 equiv) in CH_3CN (9 mL) was stirred at 40 °C. After being stirred for 24 h, the reaction mixture was concentrated under reduced pressure, diluted with ethyl acetate (12 mL), and washed with H_2O (12 mL). The water layer was extracted with ethyl acetate (12 mL) one more time. The organic layer was dried over $MgSO_4$ and concentrated under reduced pressure. The resulting residue was purified by silica gel chromatography (hexanes/ethyl acetate/dichloromethane = 30:1:2 to 10:1:2) to give **4**.

2-(2-Acetyl-1*H*-pyrrol-1-yl)-1-phenylethanone (4a). White powder, mp 127.3–127.6 °C (468.6 mg, 75%); ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.02 (d, J = 7.6 Hz, 2H), 7.62 (t, J = 7.2 Hz, 1H), 7.51 (t, J = 7.6 Hz, 2H), 7.07 (d, J = 2.4 Hz, 1H), 6.87 (s, 1H), 6.28 (s, 1H), 5.75 (s, 2H), 2.41 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 193.6, 188.9, 135.2, 133.8, 131.6, 130.5, 129.0, 128.2, 120.5, 109.0, 55.8, 27.0; HRMS (ESI-QTOF) calcd for $C_{14}H_{14}NO_2$ 228.1019 ([M + H]$^+$), found 228.1015.

2-(2-Acetyl-1*H*-pyrrol-1-yl)-1-(4-methoxyphenyl)ethanone (4b). White powder, mp 123.5–123.9 °C (587.0 mg, 83%); ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.00 (d, J = 8.4 Hz, 2H), 7.06 (s, 1H), 6.97 (d, J = 8.4 Hz, 2H), 6.86 (s, 1H), 6.27 (s, 1H), 5.72 (s, 2H), 3.88 (s, 3H), 2.40 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 192.0, 188.9, 164.0, 131.6, 130.5, 128.2, 120.4, 114.1, 108.9, 55.7, 55.3, 27.0; HRMS (ESI-QTOF) calcd for $C_{15}H_{16}NO_3$ 258.1125 ([M + H]$^+$), found 258.1121.

2-(2-Acetyl-1*H*-pyrrol-1-yl)-1-(4-chlorophenyl)ethanone (4c). White powder, mp 116.7–117.0 °C (489.2 mg, 68%); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.96 (d, J = 8.0 Hz, 2H), 7.49 (d, J = 7.6 Hz, 2H), 7.07 (s, 1H), 6.87 (s, 1H), 6.28 (s, 1H), 5.69 (s, 2H), 2.40 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 192.5, 189.0, 140.3, 133.6, 131.6, 130.4, 129.6, 129.3, 120.6, 109.1, 55.6, 27.0; HRMS (ESI-QTOF) calcd for $C_{14}H_{13}ClNO_2$ 262.0629 ([M + H]$^+$), found 262.0626.

Ethyl 2-(2-Acetyl-1*H*-pyrrol-1-yl)acetate (4d). White powder, mp 66.2–66.9 °C (456.2 mg, 85%); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.01 (d, J = 2.0 Hz, 1H), 6.83 (s, 1H), 6.22 (s, 1H), 5.00 (s, 2H), 4.23 (q, J = 7.2 Hz, 2H), 2.42 (s, 3H), 1.29 (t, J = 7.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 188.8, 168.9, 131.1, 130.6, 120.4, 108.9, 61.6, 51.4, 26.9, 14.3; HRMS (ESI-QTOF) calcd for $C_{10}H_{14}NO_3$ 196.0968 ([M + H]$^+$), found 196.0964.

General Procedure for the Synthesis of 6. To a stirred solution of **4** (0.132 mmol) in THF (2 mL) was added 60% NaH (13.2 mg, 2.5 equiv) at 0 °C. After being stirred at rt for 1 h, the reaction mixture was treated with the appropriate electrophile (1.5 equiv.). After an additional 1 h at rt, the mixture was quenched with H_2O (2 mL) and extracted with ethyl acetate (2 mL) two times. The organic layer was dried over $MgSO_4$ and concentrated under reduced pressure. The resulting residue was purified by silica gel chromatography (hexanes/ethyl acetate/dichloromethane = 50:1:2 to 30:1:2) to give **6**.

6-Phenylindolizin-8-yl Acetate (6a). Yellowish oil (29.9 mg, 90%); ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.01 (s, 1H), 7.52 (d, J = 7.2 Hz, 2H), 7.42 (t, J = 7.6 Hz, 2H), 7.38 (dd, J = 1.6, 2.8 Hz, 1H), 7.33 (t, J = 7.2 Hz, 1H), 6.80 (d, J = 0.8 Hz, 1H), 6.78 (dd, J = 2.8, 4.0 Hz, 1H), 6.39 (d, J = 4.0 Hz, 1H), 2.40 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 168.8, 142.2, 137.9, 129.1, 127.6, 127.0, 126.9, 124.2, 120.7, 114.7, 114.4, 109.4, 97.1, 21.2; IR (ATR) 3057, 1766, 1599, 1469, 1186 cm^{-1}; HRMS (ESI-QTOF) calcd for $C_{16}H_{14}NO_2$ 252.1019 ([M + H]$^+$), found 252.1021.

6-Phenylindolizin-8-yl 4-Methylbenzenesulfonate (6b). Brownish oil (44.1 mg, 92%); ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.98 (s, 1H), 7.85 (d, J = 7.5 Hz, 2H), 7.42–7.39 (m, 4H), 7.35–7.30 (m, 4H), 6.73 (s, 1H), 6.69 (d, J = 1.5 Hz, 1H), 6.30 (d, J = 2.5 Hz, 1H), 2.43 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 145.7, 141.4, 137.4, 132.9, 129.9, 129.1, 128.7, 127.7, 126.8, 126.7, 123.8, 121.3, 114.8,

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114.6, 109.9, 98.3, 21.8; IR (ATR) 3059, 2920, 1596, 1455, 1376, 1175, 1088, 759 cm^{-1}; HRMS (ESI-QTOF) calcd for $C_{21}H_{18}NO_3S$ 364.1002 ($[M + H]^+$), found 364.1002.

6-Phenylindolizin-8-yl Trifluoromethanesulfonate (6c). Light brownish oil (42.8 mg, 95%); ^1H NMR (500 MHz, $CDCl_3$) δ 8.07 (s, 1H), 7.50 (d, J = 7.0 Hz, 2H), 7.46−7.43 (m, 3H), 7.37 (t, J = 7.0 Hz, 1H), 6.93 (s, 1H), 6.86 (dd, J = 2.5, 4.0 Hz, 1H), 6.64 (d, J = 4.0 Hz, 1H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 141.2, 136.9, 129.3, 128.1, 126.8, 125.6, 123.7, 122.4, 118.9 (q, $J_{C,F}$ = 318.9 Hz), 115.7, 115.4, 109.6, 98.4; IR (ATR) 3061, 1601, 1466, 1346, 1208 cm^{-1}; HRMS (ESI-QTOF) calcd for $C_{15}H_{11}F_3NO_3S$ 342.0406 ($[M + H]^+$), found 342.0402.

6-(4-Methoxyphenyl)indolizin-8-yl Acetate (6d). Yellowish oil (36.0 mg, 97%); ^1H NMR (400 MHz, $CDCl_3$) δ 7.94 (s, 1H), 7.44 (d, J = 8.4 Hz, 2H), 7.36, (s, 1H), 6.95 (d, J = 8.4 Hz, 2H), 6. 76 (s, 2H), 6.37 (d, J = 3.2 Hz, 1H), 3.83 (s, 3H), 2.39 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 168.8, 159.2, 142.1, 130.3, 127.8, 126.8, 123.8, 120.0, 114.4, 114.4, 114.1, 109.3, 96.9, 55.5, 21.2; IR (ATR) 3035, 1765, 1608, 1464, 1244, 1180 cm^{-1}; HRMS (ESI-QTOF) calcd for $C_{17}H_{16}NO_3$ 282.1125 ($[M + H]^+$), found 282.1128.

6-(4-Methoxyphenyl)indolizin-8-yl 4-Methylbenzenesulfonate (6e). Greenish oil (46.2 mg, 89%); ^1H NMR (400 MHz, $CDCl_3$) δ 7.92 (s, 1H), 7.85 (d, J = 8.0 Hz, 2H), 7.35, (d, J = 8.8 Hz, 2H), 7.31−7.29 (m, 3H), 6.94 (d, J = 8.4 Hz, 2H), 6.70 (s, 1H), 6.68 (dd, J = 2.4, 4.0 Hz, 1H), 6.27 (d, J = 2.8 Hz, 1H), 3.84 (s, 3H), 2.43 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 159.4, 145.6, 141.3, 133.0, 129.9, 129.9, 128.7, 127.8, 126.7, 123.5, 120.6, 114.6, 114.5, 114.4, 110.0, 98.2, 55.5, 21.9; HRMS (ESI-QTOF) calcd for $C_{22}H_{20}NO_4S$ 394.1108 ($[M + H]^+$), found 394.1111.

6-(4-Methoxyphenyl)indolizin-8-yl Trifluoromethanesulfonate (6f). Light brownish oil (32.8 mg, 67%); ^1H NMR (500 MHz, $CDCl_3$) δ 8.04 (s, 1H), 7.46−7.45 (m, 1H), 7.44 (d, J = 8.5 Hz, 2H), 6.99 (d, J = 9.0 Hz, 2H), 6. 90 (s, 1H), 6.86 (dd, J = 2.5, 4.0 Hz, 1H), 6.63 (d, J = 4.0 Hz, 1H), 3.86 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 159.7, 141.2, 129.4, 128.0, 125.5, 123.4, 121.7, 118.9 (q, $J_{C,F}$ = 318.9 Hz), 115.5, 115.2, 114.7, 109.7, 98.3, 55.6; IR (ATR) 3063, 1607, 1461, 1332, 1245, 1210, 756 cm^{-1}; HRMS (ESI-QTOF) calcd for $C_{16}H_{13}F_3NO_4S$ 372.0512 ($[M + H]^+$), found 372.0510.

6-(4-Chlorophenyl)indolizin-8-yl Acetate (6g). Yellowish oil (33.2 mg, 88%); ^1H NMR (400 MHz, $CDCl_3$) δ 7.99 (s, 1H), 7.45 (d, J = 8.4 Hz, 2H), 7.40−7.38 (m, 3H), 6.79 (dd, J = 2.8, 3.6 Hz, 1H), 6.75 (s, 1H), 6.40 (d, J = 3.6 Hz, 1H), 2.41 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 168.7, 142.3, 136.4, 133.6, 129.2, 128.1, 126.9, 123.1, 120.6, 114.8, 114.6, 108.9, 97.4, 21.2; HRMS (ESI-QTOF) calcd for $C_{16}H_{13}ClNO_2$ 286.0629 ($[M + H]^+$), found 286.0626.

6-(4-Chlorophenyl)indolizin-8-yl 4-Methylbenzenesulfonate (6h). Colorless oil (44.6 mg, 85%); ^1H NMR (400 MHz, $CDCl_3$) δ 7.96 (s, 1H), 7.85 (d, J = 8.4 Hz, 2H), 7.38−7.31 (m, 7H), 6.70−6.69 (m, 2H), 6.29 (d, J = 2.8 Hz, 1H), 2.44 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 145.8, 141.5, 135.9, 133.8, 132.9, 130.0, 129.3, 128.7, 127.9, 126.8, 122.7, 121.3, 114.9, 114.9, 109.5, 98.6, 21.9; HRMS (ESI-QTOF) calcd for $C_{21}H_{17}ClNO_3S$ 398.0612 ($[M + H]^+$), found 398.0615.

6-(4-Chlorophenyl)indolizin-8-yl Trifluoromethanesulfonate (6i). Light brownish oil (36.7 mg, 74%); ^1H NMR (500 MHz, $CDCl_3$) δ 8.08 (s, 1H), 7.48 (dd, J = 1.5, 2.5 Hz, 1H), 7.46−7.42 (m, 4H), 6.89 (d, J = 4.0 Hz, 2H), 6.66 (d, J = 4.0 Hz, 1H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 141.3, 135.4, 134.2, 129.5, 128.1, 125.5, 122.6, 122.4, 118.8 (q, $J_{C,F}$ = 319.0 Hz), 115.8, 115.6, 109.2, 98.7; IR (ATR) 3065, 1596, 1463, 1327, 1300, 762 cm^{-1}; HRMS (ESI-QTOF) calcd for $C_{15}H_{10}ClF_3NO_3S$ 376.0017 ($[M + H]^+$), found 376.0016.

Synthesis of 6j and 6k. To a stirred solution of **4d** (0.154 mmol) in THF (2 mL) was added 60% NaH (27.7 mg, 4.5 equiv) at 0 °C. After being stirred at 90 °C for 1 h, the reaction mixture was treated with acetic anhydride or mesyl chloride (5 equiv) at rt. After an additional 1 h at rt, the mixture was quenched with H_2O (2 mL) and extracted with ethyl acetate (2 mL) two times. The organic layer was dried over $MgSO_4$ and concentrated under reduced pressure. The resulting residue was purified by silica gel chromatography (hexanes/ethyl acetate/dichloromethane = 10:1:2 to 5:1:2) to give **6j** or **6k**.

Indolizine-6,8-diyl Diacetate (6j). Yellowish oil (28.7 mg, 80%); ^1H NMR (500 MHz, $CDCl_3$) δ 7.84 (s, 1H), 7.32 (dd, J = 1.5, 2.5 Hz 1H), 6.76 (dd, J = 3.0, 4.0 Hz, 1H), 6.49 (d, J = 1.5 Hz, 1H), 6.42 (d, J = 4.0 Hz, 1H), 2.37 (s, 3H), 2.28 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 169.4, 168.3, 141.8, 137.5, 126.3, 115.6, 115.2, 114.3, 105.9, 97.9, 21.2, 21.1; IR (ATR) 3074, 1764, 1545, 1467, 1181 cm^{-1}; HRMS (ESI-QTOF) calcd for $C_{12}H_{12}NO_4$ 234.0761 ($[M + H]^+$), found 234.0767.

Indolizine-6,8-diyl Dimethanesulfonate (6k). Colorless oil (17.4 mg, 37%); ^1H NMR (500 MHz, $CDCl_3$) δ 8.04 (dd, J = 1.0, 1.5 Hz, 1H), 7.45 (dd, J = 1.5, 2.5 Hz, 1H), 6.89 (dd, J = 3.0, 4.0 Hz, 1H), 6.76 (d, J = 2.0 Hz, 1H), 6.68 (d, J = 4.0 Hz, 1H), 3.25 (s, 3H), 3.21 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 140.5, 135.4, 126.1, 118.5, 116.5, 115.8, 106.2, 99.7, 38.6, 37.7; IR (ATR) 3030, 1540, 1465, 1360, 962 cm^{-1}; HRMS (ESI-QTOF) calcd for $C_{10}H_{12}NO_6S_2$ 306.0101 ($[M + H]^+$), found 306.0104.

General Procedure for the Synthesis of 7. A mixture of **6** (0.161 mmol), arylboronic acid (1.5 equiv), $Pd(PPh_3)_4$ (5 mol %), and K_3PO_4 (3 equiv) in THF (2 mL) was heated at 90 °C for 2 h. After being cooled to rt, the reaction mixture was concentrated, diluted with ethyl acetate (2 mL), and washed with H_2O (2 mL). The water layer was extracted with ethyl acetate (2 mL) one more time. The organic layer was dried over $MgSO_4$ and concentrated under reduced pressure. The resulting residue was purified by silica gel chromatography (hexanes/ethyl acetate/dichloromethane = 50:1:2 to 30:1:2) to give 7.

1-(4-(6-Phenylindolizin-8-yl)phenyl)ethanone (7a). Brownish oil (34.6 mg, 69%); ^1H NMR (400 MHz, $CDCl_3$) δ 8.17 (s, 1H), 8.08 (d, J = 8.0 Hz, 2H), 7.85 (d, J = 8.0 Hz, 2H), 7.60 (d, J = 8.0 Hz, 2H), 7.46−7.44 (m, 3H), 7.37 (t, J = 7.2 Hz, 1H), 7.01 (s, 1H), 6.86 (s, 1H), 6.57 (d, J = 2.4 Hz, 1H), 2.67 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 197.9, 144.0, 138.3, 136.7, 131.9, 130.9, 129.1, 128.9, 128.6, 127.6, 126.8, 124.9, 122.7, 118.2, 114.7, 114.2, 99.5, 26.9; IR (ATR) 3056, 1724, 1602, 1450, 1263 cm^{-1}; HRMS (ESI-QTOF) calcd for $C_{22}H_{18}NO$ 312.1383 ($[M + H]^+$), found 312.1383.

1-(3-(6-Phenylindolizin-8-yl)phenyl)ethanone (7b). Brownish oil (30.1 mg, 60%); ^1H NMR (400 MHz, $CDCl_3$) δ 8.31 (s, 1H), 8.17 (s, 1H), 8.02 (d, J = 7.6 Hz, 1H), 7.95 (d, J = 7.6 Hz, 1H), 7.62−7.57 (m, 3H), 7.48−7.44 (m, 3H), 7.37 (t, J = 7.2 Hz, 1H), 6.99 (s, 1H), 6.85 (dd, J = 3.2, 3.6 Hz, 1H), 6.54 (d, J = 3.6 Hz, 1H), 2.63 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 198.1, 139.7, 138.3, 137.7, 133.0, 132.0, 131.2, 129.1, 129.1, 128.4, 128.0, 127.5, 126.8, 125.0, 122.4, 117.9, 114.6, 114.2, 99.3, 27.0; IR (ATR) 3058, 1727, 1598, 1465, 1207 cm^{-1}; HRMS (ESI-QTOF) calcd for $C_{22}H_{18}NO$ 312.1383 ($[M + H]^+$), found 312.1383.

1-(5-(6-Phenylindolizin-8-yl)thiophen-2-yl)ethanone (7c). Orange oil (40.4 mg, 79%); ^1H NMR (500 MHz, $CDCl_3$) δ 8.15 (s, 1H), 7.73 (d. J = 4.0 Hz, 1H), 7.58−7.56 (m, 3H), 7.47−7.44 (m, 3H), 7.37 (t, J = 7.5 Hz, 1H), 7.23 (d, J = 1.5 Hz, 1H), 6.89−6.85 (m, 2H), 2.60 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 190.8, 149.5, 143.2, 137.9, 132.9, 129.5, 129.2, 127.7, 126.8, 126.3, 124.9, 124.5, 123.3, 118.5, 115.0, 114.6, 100.2, 26.8; IR (ATR) 3057, 1727, 1654, 1445, 1270 cm^{-1}; HRMS (ESI-QTOF) calcd for $C_{20}H_{16}NOS$ 318.0947 ($[M + H]^+$), found 318.0947.

3-(6-Phenylindolizin-8-yl)benzonitrile (7d). Yellow gum (40.3 mg, 85%); ^1H NMR (400 MHz, $CDCl_3$) δ 8.16 (s, 1H), 8.02 (s, 1H), 7.97 (d, J = 8.0 Hz, 1H), 7.70 (d, J = 7.6 Hz, 1H), 7.59−7.58 (m, 3H), 7.48−7.44 (m, 3H), 7.37 (t, J = 7.2 Hz, 1H), 6.94 (s, 1H), 6.86 (dd, J = 2.8, 3.6 Hz, 1H), 6.50 (d, J = 3.6 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 140.5, 138.1, 132.8, 131.9, 131.6, 130.7, 129.7, 129.2, 127.6, 126.8, 124.9, 122.8, 118.9, 118.2, 114,8, 114.5, 113.0, 99.2; IR (ATR) 3060, 2228, 1598, 1478 cm^{-1}; HRMS (ESI-QTOF) calcd for $C_{21}H_{15}N_2$ 295.1230 ($[M + H]^+$), found 295.1232.

6-Phenyl-8-(pyridin-4-yl)indolizine (7e). Brownish gum (18.3 mg, 42%); ^1H NMR (400 MHz, $CDCl_3$) δ 8.72 (d, J = 5.6 Hz, 2H), 8.18 (s, 1H), 7.65 (d, J = 6.0 Hz, 2H), 7.59 (d, J = 7.6 Hz, 2H), 7.48−7.44 (m, 3H), 7.37 (t, J = 7.2 Hz, 1H), 7.02 (s, 1H), 6.87 (dd, J = 2.8, 3.2 Hz, 1H), 6.59 (d, J = 3.6 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 150.3, 146.9, 138.1, 130.3, 130.3, 129.2, 127.7, 126.8, 124.8, 123.2, 123.1, 118.3, 114.9, 114.4, 99.4; IR (ATR) 3053, 1596, 1448 cm^{-1};

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HRMS (ESI-QTOF) calcd for $C_{19}H_{15}N_2$ 271.1230 ([M + H]$^+$), found 271.1237.

Methyl 3-(6-Phenylindolizin-8-yl)benzoate (7f). Brownish gum (43.2 mg, 82%); ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.40 (s, 1H), 8.16 (s, 1H), 8.10 (d, J = 8.0 Hz, 1H), 7.94 (d, J = 7.6 Hz, 1H), 7.61 (d, J = 7.6 Hz, 2H), 7.56 (t, J = 7.6 HZ, 1H), 7.46−7.44 (m, 3H), 7.36 (t, J = 7.2 Hz, 1H), 6.99 (s, 1H), 6.85 (s, 1H), 6.54 (d, J = 3.2 Hz, 1H), 3.95 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.1, 139.5, 138.4, 132.8, 132.0, 131.2, 130.8, 129.6, 129.3, 129.1, 128.8, 127.5, 126.8, 124.9, 122.3, 117.9, 114.6, 114.2, 99.4, 52.4; IR (ATR) 3058, 1719, 1600, 1486, 1286, 1106 cm^{-1}; HRMS (ESI-QTOF) calcd for $C_{22}H_{18}NO_2$ 328.1332 ([M + H]$^+$), found 328.1334.

Methyl 4-(6-Phenylindolizin-8-yl)benzoate (7g). Yellow oil (31.1 mg, 59%); ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.15 (d, J = 7.6 Hz, 3H), 7.81 (d, J = 8.0 Hz, 2H), 7.58 (d, J = 7.6 Hz, 2H), 7.47−7.43 (m, 3H), 7.35 (t, J = 7.2 Hz, 1H), 6.99 (s, 1H), 6.85 (s, 1H), 6.56 (d, J = 3.2 Hz, 1H), 3.95 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.0, 143.8, 138.3, 131.9, 130.9, 130.1, 129.7, 129.1, 128.4, 127.5, 126.8, 124.8, 122.6, 118.1, 114.6, 114.2, 99.5, 52.3; HRMS (ESI-QTOF) calcd for $C_{22}H_{18}NO_2$ 328.1332 ([M + H]$^+$), found 328.1333.

8-(3-Nitrophenyl)-6-phenylindolizine (7h). Orange oil (32.9 mg, 65%); ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.59 (s, 1H), 8.26 (d, J = 8.0 Hz, 1H), 8.17 (s, 1H), 8.06 (d, J = 7.6 Hz, 1H), 7.64 (t, J = 7.6 Hz, 1H), 7.59 (d, J = 7.2 Hz, 2H), 7.48−7.44 (m, 3H), 7.37 (t, J = 7.2 Hz, 1H), 7.00 (s, 1H), 6.87 (s, 1H), 6.53 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 148.7, 140.8, 138.0, 134.4, 130.6, 130.5, 129.7, 129.2, 127.6, 126.8, 124.8, 123.3, 122.9, 122.9, 118.3, 114.9, 114.5, 99.2; HRMS (ESI-QTOF) calcd for $C_{20}H_{15}N_2O_2$ 315.1128 ([M + H]$^+$), found 315.1130.

8-(4-Nitrophenyl)-6-phenylindolizine (7i). Reddish solid, mp 110.0−110.5 °C (44.5 mg, 88%); ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.36 (d, J = 8.4 Hz, 2H), 8.20 (s, 1H), 7.92 (d, J = 8.8 Hz, 2H), 7.60 (d, J = 8.0 Hz, 2H), 7.50−7.46 (m, 3H), 7.39 (t, J = 8.0 Hz, 1H), 7.02 (s, 1H), 6.88 (dd, J = 2.8, 3.6 Hz, 1H), 6.55 (d, J = 3.6 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 147.5, 145.8, 138.0, 130.7, 130.4, 129.2, 129.1, 127.7, 126.8, 124.8, 124.1, 123.2, 118.7, 114.9, 114.5, 99.4; IR (ATR) 3064, 1593, 1509, 1437, 1338 cm^{-1}; HRMS (ESI-QTOF) calcd for $C_{20}H_{15}N_2O_2$ 315.1128 ([M + H]$^+$), found 315.1130.

6-(4-Methoxyphenyl)-8-(4-nitrophenyl)indolizine (7j). Orange gum (45.5 mg, 82%); ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.33 (d, J = 8.4 Hz, 2H), 8.12 (s, 1H), 7.90 (d, J = 8.8 Hz, 2H), 7.51 (d, J = 8.4 Hz, 2H), 7.46 (s, 1H), 7.00 (d, J = 8.8 Hz, 2H), 6.97 (s, 1H), 6.86 (dd, J = 3.2, 3.6 Hz, 1H), 6.52 (d, J = 4.0 Hz, 1H), 3.86 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 159.4, 147.5, 145.9, 130.6, 130.5, 130.3, 129.1, 127.9, 124.5, 124.1, 122.5, 118.8, 114.7, 114.6, 114.3, 99.3, 55.6; IR (ATR) 3078, 1594, 1505, 1462, 1338, 1248 cm^{-1}; HRMS (ESI-QTOF) calcd for $C_{21}H_{17}N_2O_3$ 345.1234 ([M + H]$^+$), found 345.1237.

3-(6-(4-Methoxyphenyl)indolizin-8-yl)benzonitrile (7k). Brown oil (20.9 mg, 40%); ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.11 (s, 1H), 8.02 (s, 1H), 7.96 (d, J = 8.0 Hz, 1H), 7.70 (d, J = 7.6 Hz, 1H), 7.59 (t, J = 7.6 Hz, 1H), 7.51 (d, J = 8.8 Hz, 2H), 7.46 (m, 1H), 7.00 (d, J = 8.8 Hz, 2H), 6.91 (s, 1H), 6.85 (dd, J = 2.8, 3.6 Hz, 1H), 6.49 (d, J = 4.0 Hz, 1H), 3.86 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 159.3, 140.5, 132.8, 131.9, 131.6, 130.6, 130.5, 130.2, 129.6, 127.8, 124.5, 122.1, 118.9, 118.3, 114.6, 114.6, 114.3, 113.0, 99.0, 55.5; IR (ATR) 3060, 2228, 1067, 1463, 1242 cm^{-1}; HRMS (ESI-QTOF) calcd for $C_{22}H_{17}N_2O$ 325.1335 ([M + H]$^+$), found 325.1337.

Methyl 4-(6-(4-Methoxyphenyl)indolizin-8-yl)benzoate (7l). Yellow oil (34.5 mg, 60%); ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.15 (d, J = 8.4 Hz, 2H), 8.09 (s, 1H), 7.81 (d, J = 8.4 Hz, 2H), 7.51 (d, J = 8.8 Hz, 2H), 7.44 (s, 1H), 6.99 (d, J = 8.4 Hz, 2H), 6.96 (s, 1H), 6.84−6.83 (m, 1H), 6.54 (d, J = 3.6 Hz, 1H), 3.96 (s, 3H), 3.85 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.0, 159.3, 143.9, 131.8, 130.8, 130.7, 130.0, 129.6, 128.4, 127.9, 124.5, 121.9, 118.2, 114.5, 114.4, 114.0, 99.3, 55.5, 52.3; IR (ATR) 3036, 1716, 1608, 1462, 1274, 1178 cm^{-1}; HRMS (ESI-QTOF) calcd for $C_{23}H_{20}NO_3$ 358.1438 ([M + H]$^+$), found 358.1437.

Heck Reaction of 6c. A mixture of **6c** (0.117 mmol), ethyl acrylate (4 equiv), $Pd(OAc)_2$ (10 mol %), tetrabutylammonium bromide (1 equiv), and $NaHCO_3$ (2 equiv) in DMF (1 mL) was heated at 100 °C for 1 h. Then the mixture was evaporated, diluted with ethyl acetate (2 mL), and washed with H_2O (2 mL). The water layer was extracted with ethyl acetate (2 mL) one more time. The organic layer was dried over $MgSO_4$ and concentrated under reduced pressure. The resulting residue was purified by silica gel chromatography (hexanes/ethyl acetate/dichloromethane = 30:1:2) to give **8** and **9**.

(2*E*,2′*E*)-Diethyl 3,3′-(6-Phenylindolizine-3,8-diyl)diacrylate (8). Brown solid, mp 158.7−159.6 °C (20.9 mg, 46%); ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.39 (s, 1H), 8.00 (d, J = 15.5 Hz, 1H), 7.92 (d, J = 16.5 Hz, 1H), 7.59 (d, J = 7.0 Hz, 2H), 7.50 (t, J = 7.5 Hz, 2H), 7.42 (t, J = 7.5 Hz, 1H), 7.38 (s, 1H), 7.31 (d, J = 4.5 Hz, 1H), 6.85 (d, J = 4.5 Hz, 1H), 6.67 (d, J = 16.0 Hz, 1H), 6.33 (d, J = 15.5 Hz, 1H), 4.33−4.26 (m, 4H), 1.37 (t, J = 7.0 Hz, 3H), 1.35 (t, J = 7.0 Hz, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 168.9, 166.8, 140.2, 137.4, 134.0, 130.0, 129.3, 128.2, 127.1, 126.7, 126.2, 122.8, 121.8, 121.4, 121.2, 117.3, 112.5, 102.1, 60.9, 60.5, 14.6, 14.5; IR (ATR) 3078, 3062, 2985, 2852, 1717, 1691, 1636, 1610, 1469 cm^{-1}; HRMS (ESI-QTOF) calcd for $C_{24}H_{24}NO_4$ 390.1700 ([M + H]$^+$), found 390.1700.

(*E*)-Ethyl 3-(6-Phenylindolizin-8-yl)acrylate (9). Brown oil (9.5 mg, 28%); ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.17 (s, 1H), 7.90 (d, J = 16.0 Hz, 1H), 7.57−7.55 (m, 2H), 7.46 (t, J = 7.5 Hz, 2H), 7.43 (dd, J = 1.5, 3.0 Hz, 1H), 7.37 (t, J = 7.5 Hz, 1H), 7.23 (s, 1H), 6.89 (dd, J = 3.0, 4.0 Hz, 1H), 6.75 (d, J = 4.0 Hz, 1H), 6.68 (d, J = 16.0 Hz, 1H), 4.30 (q, J = 7.5 Hz, 2H), 1.37 (t, J = 7.5 Hz, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 167.3, 141.6, 137.8, 129.2, 127.7, 126.8, 125.8, 124.5, 124.4, 121.1, 120.2, 115.0, 114.3, 99.3, 60.8, 14.5; IR (ATR) 3058, 3031, 2854, 1703, 1635, 1612, 1464 cm^{-1}; HRMS (ESI-QTOF) calcd for $C_{19}H_{18}NO_2$ 292.1332 ([M + H]$^+$), found 292.1333.

Synthesis of 10. A mixture of **7g** (0.0916 mmol), 3,4,5-trimethoxybenzoyl chloride (2 equiv), and Et_3N (5 equiv) in dried CH_2Cl_2 (2 mL) was heated at 80 °C for 24 h. Then the mixture was evaporated, diluted with ethyl acetate (2 mL), and washed with saturated $NaHCO_3$ solution (2 mL). The water layer was extracted with ethyl acetate (2 mL) one more time. The organic layer was dried over $MgSO_4$ and concentrated under reduced pressure. The resulting residue was purified by silica gel chromatography (hexanes/ethyl acetate/dichloromethane = 10:1:2) to give **10**.

Methyl 4-(6-Phenyl-3-(3,4,5-trimethoxybenzoyl)indolizin-8-yl)benzoate (10). Light green solid, mp 230.2−230.7 °C (26.8 mg, 56%); ^{1}H NMR (400 MHz, $CDCl_3$) δ 10.29 (s, 1H), 8.21 (d, J = 8.4 Hz, 2H), 7.78 (d, J = 8.0 Hz, 2H), 7.74 (d, J = 7.6 Hz, 2H), 7.53−7.48 (m, 4H), 7.42 (t, J = 7.2 Hz, 1H), 7.13 (s, 2H), 6.67 (d, J = 4.4 Hz, 1H), 3.98 (s, 3H), 3.95 (s, 3H), 3.93 (s, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 183.9, 166.8, 153.0, 142.6, 140.8, 137.4, 137.3, 135.9, 131.6, 130.3, 130.2, 129.3, 128.8, 128.4, 128.1, 127.2, 127.1, 125.8, 124.4, 123.4, 106.6, 102.4, 61.1, 56.4, 52.5; IR (ATR) 3055, 1719, 1609, 1456, 1234, 1180, 1130 m^{-1}; HRMS (ESI-QTOF) calcd for $C_{32}H_{28}NO_6$ 522.1911 ([M + H]$^+$), found 522.1913.

Synthesis of 11. To a stirred solution of **7h** (0.0954 mmol) in $CHCl_3$ (1 mL) were added pyridine (76.9 μg, 10 equiv) and acetyl chloride (30.5 μg, 4.5 equiv). After being stirred at rt for 3 h, the mixture was evaporated, diluted with ethyl acetate (2 mL), and washed with saturated $NaHCO_3$ solution (2 mL). The water layer was extracted with ethyl acetate (2 mL) one more time. The organic layer was dried over $MgSO_4$ and concentrated under reduced pressure. The resulting residue was purified by silica gel chromatography (hexanes/ethyl acetate/dichloromethane = 10:1:2) to give **11**.

1-(8-(3-Nitrophenyl)-6-phenylindolizin-3-yl)ethanone (11). Orange oil (10.5 mg, 31%); ^{1}H NMR (400 MHz, $CDCl_3$) δ 10.24 (s, 1H), 8.55 (d, J = 1.6 Hz, 1H), 8.33 (d, J = 8.0 Hz, 1H), 8.02 (d, J = 7.6 Hz, 1H), 7.74−7.68 (m, 3H), 7.58 (d, J = 4.8 Hz, 1H), 7.50 (t, J = 7.2 Hz, 2H) 7.45 (s, 1H), 7.41 (t, J = 7.2 Hz, 1H), 6.60 (d, J = 4.4 Hz, 1H), 2.62 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 187.3, 148.8, 139.9, 137.3, 136.2, 134.7, 130.1, 130.0, 129.3, 128.2, 128.2, 127.2, 126.0, 124.6, 124.0, 123.7, 123.4, 101.5, 27.6; IR (ATR) 3080, 1737, 1624, 1575, 1477, 1324, 1299 cm^{-1}; HRMS (ESI-QTOF) calcd for $C_{22}H_{17}N_2O_3$ 357.1234 ([M + H]$^+$), found 357.1233.

Synthesis of 12. A solution of $POCl_3$ (13.7 μL, 0.147 mmol, 3.3 equiv) in DMF (0.5 mL) was stirred at 0 °C for 1 h. To a stirred

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solution of **7i** (0.0445 mmol) in dried CH_2Cl_2 (1 mL) was added 1/3 of $POCl_3$ (1.1 equiv) and DMF mixture at 0 °C. After being stirred at rt for 1 h, the reaction mixture was quenched by saturated $NaHCO_3$ solution (2 mL), diluted with CH_2Cl_2 (2 mL), and washed with H_2O (2 mL). The water layer was extracted with ethyl acetate (2 mL) one more time. The organic layer was dried over $MgSO_4$ and concentrated under reduced pressure. The resulting residue was purified by silica gel chromatography (hexanes/ethyl acetate/dichloromethane =20:1:2 to 10:1:2) to give **12**.

8-(4-Nitrophenyl)-6-phenylindolizine-3-carbaldehyde (12). Yellow solid, mp 218.3−218.5 °C (9.4 mg, 62%); ^{1}H NMR (400 MHz, $CDCl_3$) δ 10.05 (s, 1H) 9.81 (s, 1H), 8.40 (d, J = 8.4 Hz, 2H), 7.87 (d, J = 8.4 Hz, 2H), 7.68 (d, J = 7.6 Hz, 2H), 7.53−7.49 (m, 4H), 7.43 (t, J = 7.2 Hz, 1H), 6.67 (d, J = 4.8 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 178.1, 147.9, 144.4, 137.1, 136.8, 130.4, 129.6, 129.4, 128.7, 128.4, 127.8, 127.2, 126.0, 125.4, 125.2, 124.4, 103.0; HRMS (ESI-QTOF) calcd for $C_{21}H_{15}N_2O_3$ 343.1077 ([M + H]$^+$), found 343.1077.

■ ASSOCIATED CONTENT

Ⓢ Supporting Information

^{1}H and ^{13}C NMR spectra of compounds **4**−**12**. 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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