Organic & Biomolecular Chemistry

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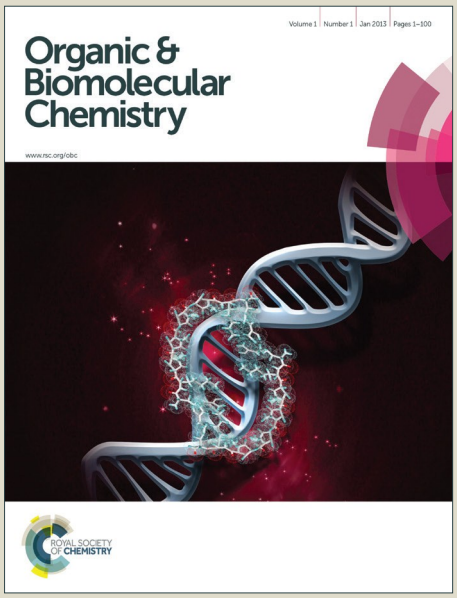

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DOI: 10.1039/C5OB02449H

Journal Name

ARTICLE

Iodine mediated intramolecular C2-amidative cyclization of indoles: A facile access to indole fused tetracycles

Received 00th January 20xx,
Accepted 00th January 20xx

DOI: 10.1039/x0xx00000x

www.rsc.org/

Sindhura Badigenchala, Venkatachalam Rajeshkumar and Govindasamy Sekar*

A novel and metal-free I_2-mediated intramolecular C2 amidation of indoles under mild reaction conditions is developed. This methodology affords various indole fused tetracyclic compounds such as benzo[4,5]imidazo[1,2-*a*]indoles by intramolecular C2 amidation of N-aryl substituted indoles. This C2 sulfonamidative cyclization also offers convenient access to indolo[2,3-*b*]indoles and dihydroindolo[2,3-*b*]quinoline from C3 aryl substituted indoles in good to excellent yields. Indolo[2,3-*b*]quinolines are also synthesized by the domino cyclization-detosylation-aromatization reaction sequence.

Introduction

The nitrogen-containing heterocycles are widespread in various natural products[1] and bioactive molecules.[2] Among these, indole is a most privileged structural motif[3] found in various biologically and pharmaceutically active molecules,[4] agrochemicals, dyes and essential oils (Figure 1).[5] Owing to its importance, indole and its derivatives have been the choice of research and much attention has been paid to synthesize and study their properties.[6a] Consequently, development of new synthetic strategies for functionalization of indole has always been the area of interest.[6]

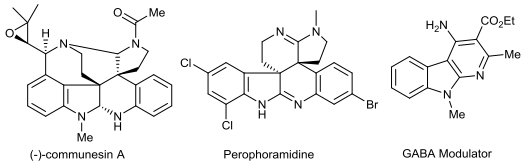


Fig. 1 Selected biologically active naturally occurring indole derivatives.

Various methodologies have been developed for the synthesis of highly functionalized indole molecules[7] and were utilized in total synthesis as well.[8] Fascinated by the importance of indole fused heterocycles, we were interested in developing a new strategy to synthesize indole fused heterocycles such as benzo[4,5]imidazo[1,2-*a*]indoles, indolo[2,3-*b*]indoles (which are very less explored in the literature)[9] and indolo[2,3-*b*]quinolones[9e-f] (Figure 2). These type of indole fused heterocyclic moieties have been generally synthesized by C-H functionalization,[7h] Cu mediated cyclization,[9b] halogen promoted cyclization,[10] gold catalyzed intramolecular cyclization,[7g,11] double C-H functionalization,[12] transition metal catalyzed annulation,[7d-f,8a] intramolecular coupling reactions.[7c,9c]

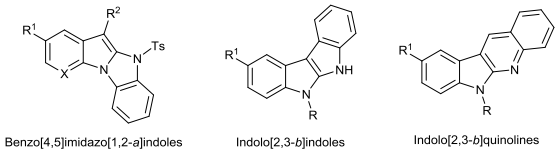
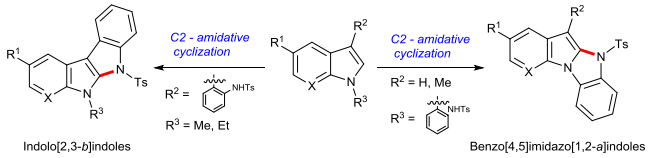


Fig. 2 Indole fused tetracycles 1, 2 and 3.

As part of our on-going research towards metal free C-N bond formation and C-H functionalization reactions,[13] we herein report iodine mediated intramolecular C2 amidative cyclization of suitably substituted indoles for the synthesis of tetracyclic indoles (Scheme 1).



Scheme 1 Intramolecular cyclization by C2-amidation of indoles.

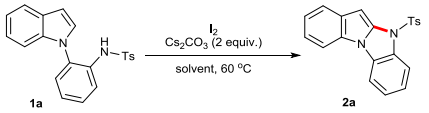
Results and Discussion

Compared with C3-functionalization of indoles, C2-functionalization is less explored and only few reports are available for C2-amination of indoles. Initially, Pd/Cu catalyzed methodologies have been developed for C2-amination of Indole.[14] Complimentary to these metal catalyzed reactions, Liang *et al.*, reported iodine mediated C2-amination of indoles[15] and recent report in this area is NIS mediated C2-amidation, by Nagarajan *et al.*[16] However, these are intermolecular reactions and only few literature reports are available for intramolecular C2-amination of indoles. Recently,

Department of Chemistry, Indian Institute of Technology Madras, Chennai 600 036, Tamil Nadu, India. E-mail: gsekar@iitm.ac.in
Electronic Supplementary Information (ESI) available: [details of any supplementary information available should be included here]. See DOI: 10.1039/x0xx00000x

transition metal catalysts[7c-e,8a] were also employed for this transformation. Ghosh *et al*. described NCS mediated cascade cyclization in which C2 amination took place.[10c] Neverthless, synthesis of the benzo[4,5]imidazo[2,3-*b*]indoles,[9a,9b] indolo[2,3-*b*]indoles[9c,9d] seldom appeared in literature. Therefore, development of a simple methodology which could give facile access to these heterocycles is desirable. To establish the intramolecular C2-amidation of indoles, initially, we treated indole derivative **1a** with 2 equiv. of iodine and 2 equiv. of Cs_2CO_3 in MeCN at room temperature. This intramolecular C2-sulfonamidative cyclization gave product benzo[4,5]imidazo[1,2-*a*]indole **2a** in 49% isolated yield after 6 hours and considerable amount of side product was also formed (Table 1, entry 1). Suspecting the side product formed might be iodinated compound of product **2a** (as excess iodine is present in reaction medium), the quantity of I_2 was reduced to 1.5 equivalents and the reaction gave 58% of **2a** (entry 2). However, reducing the amount of iodine to 1 equivalent reduced the yield of **2a** to 29% and lot of starting material was left unreacted (entry 3). Increasing the reaction temperature to 60 °C increased the yield to 57% (entry 4).

Table 1 Optimization of reaction conditions for C2 amidative cyclization[a]

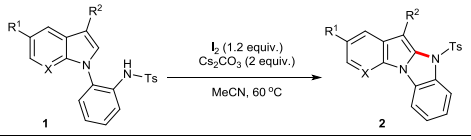


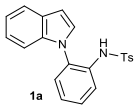
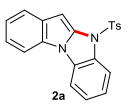
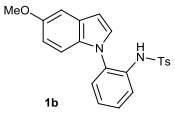
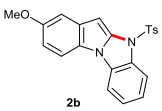
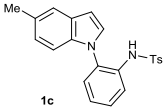
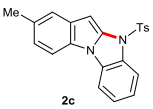
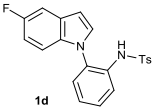
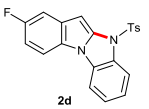
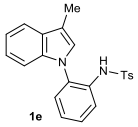
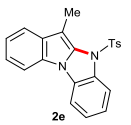
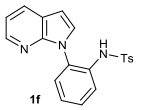
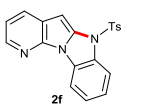
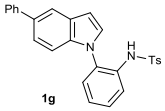
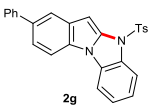
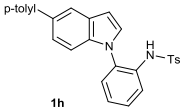
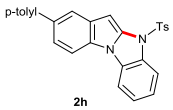
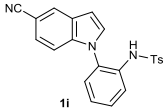
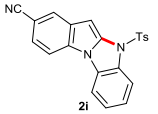
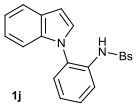
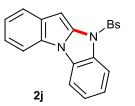
Entry	I_2 (equiv.)	Solvent	Temp (°C)	Time (h)	Yield[b] (%)
1	2	MeCN	rt	6	49
2	1.5	MeCN	rt	4	58
3	1.0	MeCN	rt	24	29
4	1.0	MeCN	60	15	57
5	1.5	MeCN	60	5	50
6	1.2	MeCN	60	6	62
7	1.2	MeCN	60	6	75[c]
8	1.2	CCl_4	60	6	60
9	1.2	Toluene	60	7	42
10	1.2	THF	60	5	65
11	1.2	DMSO	60	6	67
12	1.2	EtOH	60	9	45

[a] Reaction conditions: 1a (0.5 mmol), Cs_2CO_3 (1 mmol) in solvent (3 mL) at given temperature. [b] Isolated yield. c I_2 is added in two equal portions.

To increase the efficiency of this intramolecular C2-amidation reaction, the quantity of iodine was increased to 1.5 equivalent, and the reaction yielded only 50% of **2a** (entry 5). When the reaction was carried out using 1.2 equivalent of iodine at 60 °C, the yield was increased to 62% and the side product was considerably reduced (entry 6). Addition of iodine in two equal portions resulted in 75% of **2a** (entry 7) without formation of any side products. Further changing the reaction conditions did not increase the yield of **2a** (Table 1). Use of solvents such as CCl_4, toluene, THF, DMSO and ethanol failed to increase the yield of the product (entries 8-12) and MeCN was found to be the best solvent. Similarly, Cs_2CO_3 turned out to be the choice of base compared with bases such as K_2CO_3, KOH, NaO^tBu, K_3PO_4 etc. From the optimization studies, the best reaction condition for this C2-sulfonamidative cyclization was found to be, iodine (1.2 equiv.), Cs_2CO_3 (2 equiv.) in 2 mL MeCN at 60 °C (entry 7). With the optimized reaction conditions in hand, we have investigated the substrate scope of the methodology and the results are summarized in Table 2. All the substrates gave very good to satisfactory yields of the products. Electron releasing groups such as 5-methoxy, 5-methyl, 3-methyl, 5-phenyl and 5-p-tolyl attached to indole gave benzo[4,5]imidazo[1,2-*a*]indoles in moderate to good yield (entries 2, 3, 5, 7 and 8). Presence of electron withdrawing fluoro, cyano groups also provided the C2-cyclized products **2d** and **2i** in 72 and 45% yield respectively (entries 4 and 9). 7-Azaindole derivative also rendered the corresponding product **2e** in 70% yield (entry 6).

Table 2 Substrate scope of I_2 mediated C2-amidative cyclization.[a]

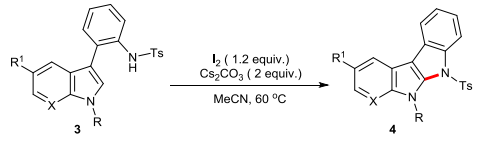


Entry	Substrate	Product	Time (h)	Yield (%)[b]
1.	 1a	 2a	6	75
2.	 1b	 2b	4.5	80
3.	 1c	 2c	5	76
4.	 1d	 2d	6	72
5.	 1e	 2e	8	60
6.	 1f	 2f	5	70
7.	 1g	 2g	6	56
8.	 1h	 2h	5	65
9.	 1i	 2i	8	45
10.	 1j	 2j	8	62

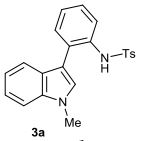
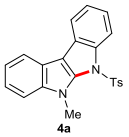
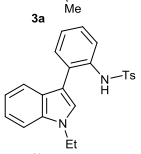
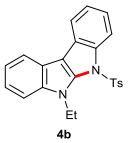
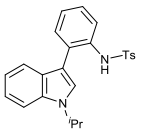
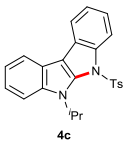
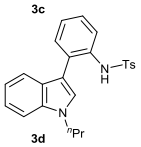
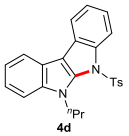
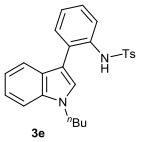
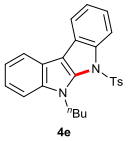
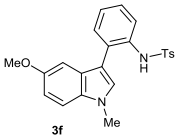
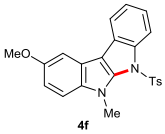
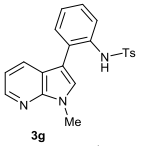
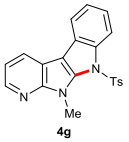
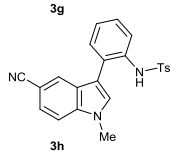
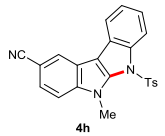
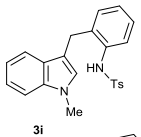
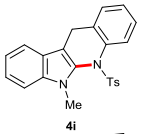
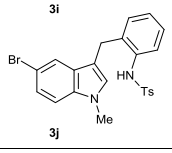
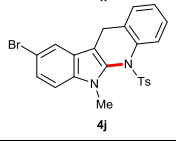
[a] Reaction conditions: **1** (0.5 mmol), I_2 (0.6 mmol), Cs_2CO_3 (1 mmol) in MeCN (3 mL) at 60 °C. [b] Isolated yield.

When the tosyl protection on nitrogen was replaced with brosyl group, corresponding indole derivative was also readily underwent for cyclization to yield 62% of the product (entry 10).

Table 3 Substrate scope of I_2 mediated C2-amidaitve cyclization.[a]

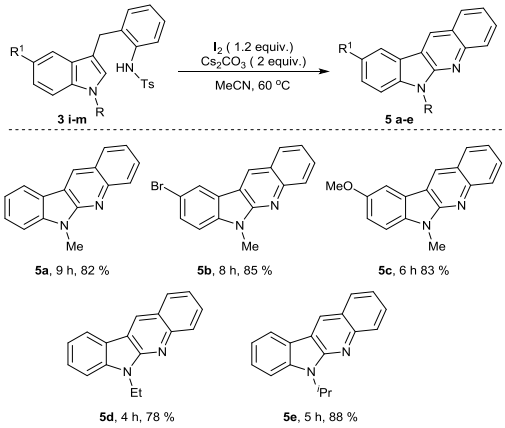


3 4

Entry	Substrate	Product	Time (h)	Yield[b] (%)
1.	 3a	 4a	5	95
2.	 3b	 4b	6	76
3.	 3c	 4c	6	96
4.	 3d	 4d	6	92
5.	 3e	 4e	5	92
6.	 3f	 4f	5	80
7.	 3g	 4g	5	78
8.	 3h	 4h	7	82
9.	 3i	 4i	5	65
10.	 3j	 4j	6	68

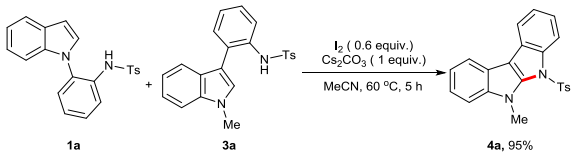
[a] Reaction conditions: **3** (0.5 mmol), I_2 (0.6 mmol), Cs_2CO_3 (1 mmol) in MeCN (3 mL) at 60 °C. [b] Isolated yield.

In order to explore the generality of this methodology, C3 arylated indole **3a** was subjected to the optimized reaction condition. To our delight, this reaction afforded 95% yield of indolo[2,3-*b*]indole **4a** in 5 hours (Table 3). Encouraged with this result, we explored the substrate scope of this type of compounds and all the substrates gave good to excellent yields of the indolo[2,3-*b*]indoles (Table 3). Substrates bearing *N*-ethyl, *N*-isopropyl, *N*-propyl and *N*-butyl substituents gave excellent yields of cyclized products (entry 2-5). 5-Methoxy and 5-cyano substituted *N*-methyl indoles gave 80% and 82% yields of products (entries 6 and 8). *N*-methyl 7-azaindole derivative also yielded 78% of the product 4g (entry 7). In this context to further extend scope of this cyclization, compounds **3i** and **3j** were also cyclized to give corresponding products, dihydroindolo[2,3-*b*]quinolines **4i** and **4j** respectively (entries 9 and 10). In the cyclization reaction of **3i**, trace amount of another product was also isolated which was analysed as **5a**. This compound was expected to have formed by the detosylation and aromatization sequence of **4i**. Prolonging the reaction time in case of substrates **3i** and **3j** resulted in cyclization followed by detosylation and aromatization, affording indolo[2,3-*b*]quinolines **5a** and **5b** respectively (Scheme 2). In contrast, subtrates with 5-methoxy *N*-ethyl and *N*-isopropyl substituents (**3k**, **3l** and **3m**) gave exclusively the aromatized indoloquinolines (**5c**, **5d** and **5e**) and not even trace amount of dihydroindoloquinolines were detected (Scheme 2).



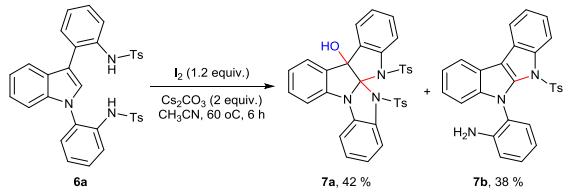
Scheme 2 I_2-mediated domino C2 amidative cyclization followed by detosylation and aromatization.

To examine which substrate is more facile for the C-N bond forming cyclization reaction, the intermolecular competitive reaction between **1a** and **3a** has been performed. As expected, the reaction resulted selectively in 95% of **4a** in 5 hours and only trace amount of **2a** was detected (Scheme 3).



Scheme 3 Intermolecular competitive reaction between **1a** and **3a**.

This shows that the C2 amidaton of substrate **3a**, where aryl group is tethered to C3 is more facile yielding major quantity of the product. Further to carry out the intramolecular competitive cyclization reaction, compound **6a** has been prepared and subjected to the reaction conditions. Surprisingly this reaction afforded 42% of novel indole fused hexacyclic compound **7a**, which was formed by double cyclization and further nucleophilic substitution of iodine at C3 by hydroxy ion (Scheme 4). This reaction also yielded 38% of monocyclized–detosylated compound **7b**. Structure of compound **7a** is unambiguously established by XRD analysis (Figure 3).



Scheme 4 Intramolecular competitive reaction.

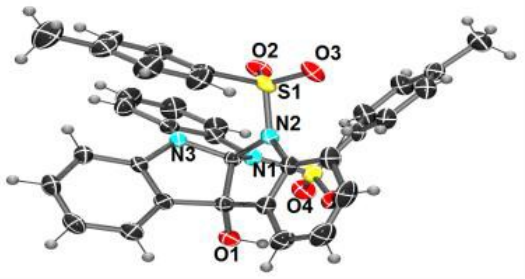
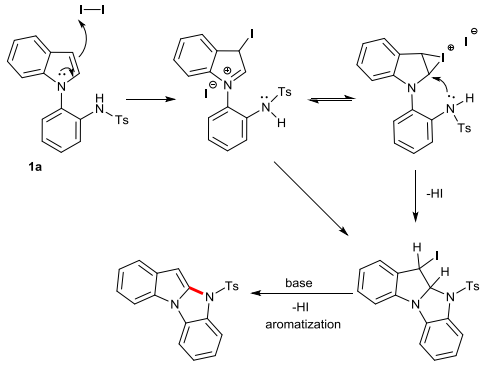


Fig. 3 ORTEP diagram of compound **7a** (CCDC 142079). Ellipsoids represent 30% probability.

It is expected that the reaction may proceed via formation of cyclic iodonium ion which may undergo intramolecular cyclization by nucleophilic attack of amine to open iodonium ion (Scheme 5). Subsequent elimination of HI in presence of base may yield corresponding cyclized products.



Scheme 5. Proposed reaction mechanism for intramolecular amidation of indoles.[15]

Conclusions

In conclusion, we have developed a novel, metal-free and efficient, iodine mediated intramolecular sulfonamidation of indoles to give general access to different indole fused heterocycles like indolo[2,3-*b*]indoles, benzo[4,5]imidazo[1,2-*a*]indoles and indolo[2,3-*b*]quinolines. Under the optimized reaction conditions, C2 position is amidated than the more reactive C3 position. The competitive intermolecular reaction shows that indole substrate with aryl group tethered to C3 position (**3a**) is more reactive than corresponding indole substrate with aryl group tethered to nitrogen of indole. Further Indolo[2,3-*b*]quinolines were also synthesized by the domino cyclization-detosylation-aromatization sequence.

Experimental Section

General considerations:

All reactions were carried out in reaction tubes closed with stoppers and in an undistilled solvents. All the solvents used for the reactions were obtained from Fischer Scientific, India Pvt. Ltd. Reactions were monitored by thin-layer chromatography (TLC) using Merck silica gel 60 F_{254} precoated plates (0.25 mm) and visualized by UV fluorescence quenching using appropriate mixture of ethyl acetate and hexanes. Silica gel (particle size: 100-200 mesh) was purchased from Avra and used for column chromatography using hexanes and ethyl acetate mixture as eluent. Cs_2CO_3 was purchased from Sigma-Aldrich Company. Other reagents such as Indole, Iodine were purchased from Spectrochem, India Pvt. Ltd., 2-fluoro nitrobenzene and 2-bromo nitrobenzene were obtained from Avra synthesis Pvt. Ltd. India. Various substituted indoles were obtained from Spectrochem India Pvt. Ltd and Alfa Aesar Company. All the reactions were carried out in temperature controlled IKA magnetic stirrers. ^{1}H and ^{13}C NMR spectra were recorded on a Bruker 400 instrument. ^{1}H NMR spectra were reported relative to Me_4Si (δ 0.0 ppm) or residual $CDCl_3$ (δ 7.26 ppm). ^{13}C NMR were reported relative to $CDCl_3$ (δ 77.16 ppm). FTIR spectra were recorded on a Nicolet 6700 spectrometer and were reported in frequency of absorption (cm^{-1}). High resolution mass spectra (HRMS) were recorded on Q-Tof Micro mass spectrometer. Melting points were measured either on a Toshniwal melting point apparatus or on a Kofler-Heizitschmikroskop apparatus.

General procedure for Iodine mediated intramolecular C2 amidative cyclization of compounds 1a-j:

Indole derivative **1** (0.5 mmol) was taken in a clean, dry reaction tube. To this iodine (0.3 mmol), Cs_2CO_3 (1.0 mmol) and acetonotrile (2 mL) were added. Reaction tube was stoppered and the resulting reaction mixture was stirred at 60 ^oC. After 4 h the second portion of iodine (0.3 mmol) was added and reaction was allowed to stir at 60 ^oC. Upon completion of reaction was monitored by TLC, then the solvent was removed under vacuum in rotary evaporator and DCM was added. The crude reaction mixture was washed with $Na_2S_2O_3$ solution (2 × 10 mL) and extracted with DCM. The organic layer was washed water (1 × 10 mL). Combined organic layers were concentrated using rotary evaporator and residue was purified by column chromatography on silica gel using hexanes/ethyl acetate as the eluent to afford pure product **2**.

10-Tosyl-10H-benzo[4,5]imidazo[1,2-*a*]indole (2a): White solid, mp 148-150 ^{o}C; R_f 0.50 (15% ethyl acetate in hexanes); ^{1}H NMR ($CDCl_3$, 400 MHz) δ 2.28 (s, 3H), 6.57 (d, *J*=0.4 Hz, 1H), 7.22 (m, 3H), 7.33 (dt, *J*=8, 1.2 Hz, 1H), 7.59 (dd, *J*=1., 0.4 Hz, 1H), 7.68-7.72 (m, 2H), 7.79 (d, *J*=8.4 Hz, 2H), 8.04 (dd, *J*=8, 0.4 Hz, 1H) ; ^{13}C NMR ($CDCl_3$, 100 MHz) δ 21.7, 82.1, 110.5, 110.7, 115.1, 120.7, 121.2, 121.7, 123.1, 125.1, 127.0, 127.1, 129.8, 130.0, 132.5, 133.6, 138.9, 145.7; FTIR (KBr) 2922, 2856, 1578, 1492, 1377, 1177, 1019 cm^{-1}; HRMS (*m/z*): $[M+H]^+$ calcd. for $C_{21}H_{17}N_2O_2S$: 361.1011; found: 361.0999.

2-Methoxy-10-tosyl-10H-benzo[4,5]imidazo[1,2-*a*]indole (2b): Pale brown solid, mp 142-144 ^{o}C; R_f 0.51 (20% ethyl acetate in hexanes); ^{1}H NMR ($CDCl_3$, 400 MHz) δ 2.28 (s, 3H), 3.89 (s, 3H), 6.49 (s, 1H), 6.87 (dd, *J*=8.8 Hz, 1H), 7.13 (d, *J*=8 Hz, 2H), 7.17 (d, *J*=2.4 Hz, 1H), 7.22 (dt, *J*=8, 1.2 Hz, 1H), 7.31 (dt, *J*=7.6, 1.2 Hz, 1H), 7.52 (d, *J*=8 Hz, 1H), 7.56 (d, *J*=8.8 Hz, 1H), 7.79 (d, *J*=8.4 Hz, 2H), 8.02 (dd, *J*=8, 0.8 Hz, 1H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 21.7, 56.0, 103.7, 110.0, 110.1, 111.3, 115.0, 122.1, 122.7, 125.1, 127.1, 128.3, 130.0, 133.3, 133.4, 133.7, 139.4, 145.7, 155.5; FTIR (KBr) 3065, 2924, 2854, 1598, 1577, 1490 cm^{-1}; HRMS (*m/z*): $[M+H]^+$ calcd. for $C_{22}H_{19}N_2O_3S$: 391.1116; found: 391.1102.

2-Methyl-10-tosyl-10H-benzo[4,5]imidazo[1,2-*a*]indole (2c): White solid, mp 155-158 ^{o}C; R_f 0.52 (15% ethyl acetate in hexanes); ^{1}H NMR ($CDCl_3$, 400 MHz) δ 2.27 (s, 3H), 2.49 (s, 3H), 6.48 (s, 1H), 7.06 (dd, *J*=8.4, 1.2 Hz, 1H), 7.12 (d, *J*=8 Hz, 2H), 7.22 (dt, *J*=8, 1.2 Hz, 1H), 7.31 (dt, *J*=7.8, 1.2 Hz, 1H), 7.49 (s, 1H), 7.53-7.58 (m, 2H), 7.78 (d, *J*=8.4 Hz, 2H), 8.02 (d, *J*=8 Hz, 1H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 21.7, 21.8, 81.7, 110.3, 115.1, 121.0, 122.1, 122.8, 125.1, 125.3, 127.1, 128.3, 129.9, 129.9, 131.2, 132.8, 133.5, 133.6, 139.0, 145.6; FTIR (KBr) 3061, 2923, 2858, 1600, 1575, 1495, 1457, 1377cm^{-1}.

2-Fluoro-10-tosyl-10H-benzo[4,5]imidazo[1,2-*a*]indole (2d): Pale yellow solid, mp 162-165 ^{o}C; R_f 0.50 (15% ethyl acetate in hexanes); ^{1}H NMR ($CDCl_3$, 400 MHz) δ 2.29 (s, 3H), 6.53 (s, 1H), 6.97 (dt, *J*=9.2, 2.4 Hz, 1H), 7.15 (q, *J*=8.8 Hz, 3H), 7.31-7.37 (m, 2H), 7.56 (d, *J*=7.8 Hz, 1H), 7.59 (dd, *J*=8.8, 8.4 Hz, 1H), 7.80 (d, *J*=8.4 Hz, 2H), 8.04 (d, *J*=8 Hz, 1H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 21.7, 82.1, 106.4, 106.6, 108.5, 108.8, 110.2, 111.2, 111.3, 115.1, 123.2, 125.1, 127.1, 127.8, 128.3, 129.5, 130.0, 133.3, 145.9; ^{19}F NMR (C_6F_6, 500 MHz) δ -124.47; FTIR (KBr) 2923, 2855, 1568, 1489, 1466, 1458 cm^{-1}.

11-Methyl-10-tosyl-10H-benzo[4,5]imidazo[1,2-*a*]indole (2e): White solid, mp 158-160 ^{o}C; R_f 0.45 (10% ethyl acetate in hexanes); ^{1}H NMR ($CDCl_3$, 400 MHz) δ 2.14 (s, 3H), 2.60 (s, 3H), 6.93 (d, *J*=8 Hz, 2H), 7.10 (dt, *J*=8, 1.2 Hz, 1H), 7.16-7.24 (m, 3H), 7.35-7.42 (m, 3H), 7.49-7.55 (m, 1H), 7.57-7.62 (m, 1H), 8.01 (dd, *J*=8, 0.4 Hz, 1H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 9.3, 21.6, 94.8, 109.8, 110.4, 117.6, 119.6, 121.1, 121.4, 122.5, 125.9, 126.8, 127.3, 129.7, 130.6, 133.6, 135.0, 145.1; FTIR (KBr) 3057, 2923, 2859, 1603, 1499, 1365, 1242, 1176 cm^{-1}; HRMS (*m/z*): $[M+H]^+$ calcd. for $C_{22}H_{19}N_2O_2S$: 375.1167; found: 375.1176.

6-Tosyl-6H-benzo[4',5']imidazo[1',2':1,5]pyrrolo[2,3-*b*]pyridine (2f): White solid, mp 140-142 ^{o}C; R_f 0.48 (20% ethyl acetate in hexanes); ^{1}H NMR ($CDCl_3$, 500 MHz) δ 2.29 (s, 3H), 6.51 (s, 1H), 7.15 (d, *J*=8 Hz, 2H), 7.21 (dd, *J*=8 Hz, 1H), 7.29 (dt, *J*=8, 1.5 Hz, 1H), 7.36 (dt, *J*=5, 1 Hz, 1H), 7.79 (d, *J*=8.5 Hz, 2H), 7.98 (dd, *J*=8, 1.5 Hz, 1H), 8.02 (d, *J*=7.5 Hz, 1H), 8.12 (d, *J*=8 Hz, 1H), 8.32 (dd, *J*=4.5, 1.5 Hz, 1H); ^{13}C NMR ($CDCl_3$, 125 MHz) δ 21.7, 112.8, 114.8, 117.7, 124.0, 125.5, 127.1, 128.6, 128.8, 130.0, 133.4, 133.5, 139.0, 140.9, 146.0; FTIR (KBr) 3060, 2923, 2851, 1599, 1553, 1496, 1428 cm^{-1}; HRMS (*m/z*): $[M+H]^+$ calcd. for $C_{20}H_{16}N_3O_2S$: 362.0963; found: 362.0975.

2-Phenyl-10-tosyl-10H-benzo[4,5]imidazo[1,2-*a*]indole (2g): White solid, mp 173-175 ^{o}C; R_f 0.41 (15% ethyl acetate in hexanes); ^{1}H NMR ($CDCl_3$, 400 MHz) δ 2.19, (s, 3H), 6.52 (s, 1H), 7.05 (d, *J*=8 Hz, 2H), 7.14-7.19 (m, 1H), 7.22-7.28 (m, 2H), 7.35-7.41 (m, 3H), 7.51 (d, *J*=8 Hz, 1H), 7.56-7.60 (m, 2H), 7.64 (d, *J*=8.4 Hz, 1H), 7.72 (d, *J*=8.4 Hz, 2H), 7.81 (d, *J*=1.2 Hz, 1H), 7.96 (d, *J*=8 Hz, 1H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 21.7, 110.5, 110.9, 115.1, 119.7, 120.4, 123.1, 125.2, 126.4, 126.8, 127.1, 127.6, 128.9, 129.7, 130.0, 133.1, 133.6, 135.3, 139.4, 142.3; FTIR (KBr) 3059, 2923, 2856, 1602, 1574, 1489, 1468 cm^{-1}; HRMS (*m/z*): $[M+H]^+$ calcd. for $C_{27}H_{21}N_2O_2S$: 437.1324; found: 437.1340.

2-(*p*-Tolyl)-10-tosyl-10H-benzo[4,5]imidazo[1,2-*a*]indole (2h): Light brown solid, mp 165-167 ^{o}C; R_f 0.43 (15% ethyl acetate in hexanes); ^{1}H NMR ($CDCl_3$, 400 MHz) δ 2.19 (s, 3H), 2.33 (s, 3H), 6.51 (s, 1H), 7.05 (d, *J*=8.4 Hz, 2H), 7.15-7.21 (m, 3H), 7.24 (dt, *J*=7.6, 1.2 Hz, 1H), 7.37 (dd, *J*=8.4, 2.0 Hz, 1H), 7.45-7.55 (m, 3H), 7.63 (d, *J*=8.4 Hz, 1H), 7.71 (d, *J*=8.4 Hz, 2H), 7.79 (d, *J*=1.2 Hz, 1H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 21.2, 21.7, 82.3, 110.5, 110.8, 115.1, 119.5, 120.3, 123.1, 125.2, 126.3, 127.1, 127.4, 129.6, 129.7, 130.0, 133.0, 133.5, 133.5, 135.2, 136.5, 139.3, 145.7; FTIR (KBr) 3029, 2921, 2856, 1602, 1575, 1490, 1458, 1375, 1317 cm^{-1}; HRMS (*m/z*): $[M+H]^+$ calcd. for $C_{28}H_{23}N_2O_2S$: 451.1480; found: 451.1461.

10-Tosyl-10H-benzo[4,5]imidazo[1,2-*a*]indole-2-carbonitrile (2i): Pale brown solid, mp 220-222 ^{o}C; R_f 0.50 (50% ethyl acetate in hexanes); ^{1}H NMR ($CDCl_3$, 400 MHz) δ 2.30 (s, 3H), 6.61 (s, 1H), 7.17 (d, *J*=8.4 Hz, 2H), 7.31-7.40 (m, 2H), 7.47 (dd, *J*=8.2, 1.2 Hz, 1H), 7.61-7.65 (m, 1H), 7.74 (d, *J*=8.4 Hz, 1H), 7.80 (d, *J*=8.4 Hz, 2H), 8.01 (d, *J*=1.2 Hz, 1H), 8.04-8.09 (m, 1H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 21.7, 82.1, 104.9, 111.1, 111.4, 115.2, 120.4, 123.6, 124.4, 125.3, 126.0, 127.1, 128.2, 128.7, 130.1, 132.2, 133.4, 133.6, 140.4, 146.2; FTIR (KBr) 2922, 2854, 2221, 1603, 1566, 1490, 1375 cm^{-1}.

10-((4-Bromophenyl)sulfonyl)-10H-benzo[4,5]imidazo[1,2-*a*]indole (2j): Pale green solid, mp 148-150 ^{o}C; R_f 0.46 (10% ethyl acetate in hexanes); ^{1}H NMR ($CDCl_3$, 400 MHz) δ 6.48 (s, 1H), 7.15-7.21 (m, 3H), 7.26 (dt, *J*=8, 0.8 Hz, 1H), 7.39 (d, *J*=8.8 Hz, 2H), 7.52 (d, *J*=8 Hz), 7.60-7.64 (m, 2H), 7.66 (d, *J*=8.8 Hz, 2H), 7.93 (d, *J*=8 Hz, 1H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 21.7, 82.1, 110.5, 110.7, 115.1, 120.7, 121.2, 121.7, 123.1, 125.1, 127.0, 127.1, 129.8, 130.0, 132.5, 133.6, 138.9, 145.7; FTIR (KBr) 3062, 1605, 1572, 1494, 1457, 1385 cm^{-1}. HRMS (*m/z*): $[M+H]^+$ calcd. for $C_{20}H_{14}N_2O_2SBr$: 424.9959; found:424.9980 (HRMS data for ^{79}Br isotope).

General procedure for C2 amidative cyclization of compounds 3a-i:

Indole derivative **3** (0.5 mmol) was taken in a clean and dry reaction tube. To this iodine (0.6 mmol), Cs_2CO_3 (1.0 mmol) and acetonotrile (2 mL) was added. Reaction tube is stoppered

and the resulting reaction mixture was stirred at 60 °C. After 4 h the second portion of iodine (0.3 mmol) was added and reaction was allowed to stir at 60 °C. Upon completion of reaction as monitored by TLC, solvent was removed under vacuum in rotary evaporator and DCM was added. The crude reaction mixture was washed with saturated $Na_2S_2O_3$ solution (2 × 10 mL) and extracted with DCM. The organic layer was washed water (1 × 10 mL). Combined organic layers were concentrated using rotary evaporator and residue is purified by column chromatography on silica gel using hexanes/ethyl acetate as an eluent to afford pure product **4**.

5-Methyl-6-tosyl-5,6-dihydroindolo[2,3-*b*]indole (4a)[10]: White solid, mp 164-166 °C [lit. 162 °C][10]; R_f 0.56 (10% ethyl acetate in hexanes); ^{1}H NMR ($CDCl_3$, 400 MHz) δ 2.11 (s, 3H), 4.13 (s, 3H), 6.86 (d, *J*=8.4 Hz, 2H), 7.11 (dt, *J*=7.6, 1.2 Hz, 1H), 7.15-7.30 (m, 5H), 7.41 (d, *J*=8 Hz, 1H), 7.50 (dd, *J*=7.6, 0.8 Hz, 1H), 7.71 (d, *J*=7.6 Hz, 1H), 8.07 (dd, *J*=8.4, 0.8 Hz, 1H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 21.6, 34.0, 111.0, 118.0, 118.5, 119.5, 120.5, 121.0, 122.3, 122.4, 125.6, 127.0, 129.4, 132.5, 140.7, 141.7, 143.0, 145.0; FTIR (KBr) 3057, 2923, 2853, 1600, 1528, 1505, 1436, 1396, 1368, 1175 cm^{-1}; HRMS (*m/z*): $[M+H]^+$ calcd. for $C_{22}H_{19}N_2O_2S$: 375.1167; found: 375.1166.

5-Ethyl-6-tosyl-5,6-dihydroindolo[2,3-*b*]indole (4b): Pale brown solid, mp 156-158 °C; R_f 0.55 (10% ethyl acetate in hexanes); ^{1}H NMR ($CDCl_3$, 400 MHz) δ 1.48 (t, *J*=7.2 Hz, 3H), 2.11 (s, 3H), 4.70 (q, *J*=7.2 Hz, 2H), 6.86 (d, *J*=8.4 Hz, 2H), 7.11 (dt, *J*=7.6, 1.2 Hz, 1H), 7.15-7.21 (m, 2H), 7.21-7.29 (m, 3H), 7.45 (d, *J*=8 Hz, 1H), 7.49 (td, *J*=7.6, 0.8 Hz, 1H), 7.72dd, *J*=7.4, 0.8 Hz, 1H), 8.07 (dd, *J*=8.2, 0.8 Hz, 1H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 15.0, 21.6, 41.8, 109.6, 111.3, 117.9, 118.4, 119.6, 120.9, 122.3, 125.6, 127.0, 127.3, 129.4, 132.5, 140.8, 141.0, 142.5, 144.9; FTIR (KBr) 3056, 2926, 2859, 1604, 1515, 1453, 1370, 1251, 1176 cm^{-1}; HRMS (*m/z*): $[M+H]^+$ calcd. for $C_{23}H_{21}N_2O_2S$: 389.1324; found: 389.1313.

5-Isopropyl-6-tosyl-5,6-dihydroindolo[2,3-*b*]indole (4c): White solid, mp 138-140 °C; R_f 0.46 (20% ethyl acetate in hexanes); ^{1}H NMR ($CDCl_3$, 400 MHz) δ 1.74 (d, *J*=7.2 Hz, 6H), 2.17 (s, 3H), 5.64 (septet, *J*=7.2 Hz, 1H), 6.88 (s, 1H), 6.89 (d, *J*=8 Hz 2H), 7.15-7.22 (m, 3H), 7.23-7.29 (m, 3H), 7.49 (dd, *J*=7.6, 0.8 Hz, 1H), 7.73-7.79 (m, 2H), 8.11 (d, *J*=8 Hz, 1H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 21.6, 21.7, 51.8, 114.5, 118.3, 118.8, 120.0, 120.7, 121.6, 122.1, 122.3, 125.9, 127.2, 128.1, 129.1, 131.3, 139.4, 141.4, 143.7, 144.8; FTIR (KBr) 3058, 2973, 2927, 2854, 1604, 1531, 1504, 1457, 1172 cm^{-1}.

5-propyl-6-tosyl-5,6-dihydroindolo[2,3-*b*]indole (4d): White solid, mp 138-140 °C; R_f 0.46 (20% ethyl acetate in hexanes); ^{1}H NMR ($CDCl_3$, 400 MHz) δ 0.94 (t, *J*=7.6 Hz, 3H), 2.01 (sextet, *J*=7.6 Hz, 2H), 2.19 (s, 3H), 4.69 (t, *J*=7.6 Hz, 2H), 6.93 (d, *J*=8.0 Hz, 2H), 7.19 (dt, *J*=8.4, 1.2 Hz, 1H), 7.21-7.29 (m, 2H), 7.30-7.35 (m, 3H), 7.52 (d, *J*=8.0 Hz, 1H), 7.58 (dd, *J*=3.6, 0.8 Hz, 1H), 7.80 (d, *J*=7.2 Hz, 1H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 11.4, 21.6, 22.9, 48.2, 109.5, 111.4, 117.9, 118.4, 119.5, 120.6, 120.8, 122.1, 122.4, 125.5, 126.9, 127.3, 129.3, 132.3, 140.7, 141.2, 142.5, 144.9; FTIR (KBr) 3058, 2965, 2927, 2865, 1604, 1511, 1454, 1176 cm^{-1}.

5-butyl-6-tosyl-5,6-dihydroindolo[2,3-*b*]indole (4e): White solid, mp 138-140 °C; R_f 0.46 (20% ethyl acetate in hexanes); ^{1}H NMR ($CDCl_3$, 400 MHz) δ 0.96 (t, *J*=7.6 Hz, 3H), 1.35 (sextet, *J*=7.6 Hz, 2H), 1.94 (quintet, *J*=7.6 Hz, 2H) 2.19 (s, 3H), 4.74 (t, *J*=7.6 Hz, 2H), 6.94 (d, *J*=8.0 Hz, 2H), 7.19 (dt, *J*=8.0, 1.2 Hz, 1H), 7.23-7.29 (m, 2H), 7.32 (d, *J*=8.4 Hz, 3H), 7.52 (d, *J*=8.4 Hz, 1H), 7.58 (d, *J*=7.6 Hz, 1H), 7.80 (d, *J*=7.6 Hz, 1H), 8.16 (d, *J*=8.4 Hz, 1H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 14.0, 20.2, 21.6, 31.6, 46.5, 109.5, 111.4, 118.0, 118.4, 119.5, 120.7, 120.8, 122.1, 122.4, 125.6, 126.9, 127.3, 129.3, 132.3, 140.7, 141.1, 142.5, 144.9; FTIR (KBr) 3058, 2965, 2927, 2865, 1604, 1511, 1457, 1373, 1176 cm^{-1}.

2-Methoxy-5-methyl-6-tosyl-5,6-dihydroindolo[2,3-*b*]indole (4f): Pale green solid, mp 162-164 °C; R_f 0.43 (15% ethyl acetate in hexanes); ^{1}H NMR ($CDCl_3$, 400 MHz) δ 2.11 (s, 3H), 3.82 (s, 3H), 4.08 (s, 3H), 6.83-6.92 (m, 3H), 7.10 (dt, *J*=8.4, 1.2 Hz, 1H), 7.15-7.21 (m, 2H), 7.23 (d, *J*=8.4 Hz, 2H), 7.28 (d, *J*=8.8 Hz, 1H), 7.47 (d, *J*=7.4 Hz, 1H), 8.05 (d, *J*=8.4 Hz, 1H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 21.6, 34.0, 56.1, 102.5, 108.8, 111.3, 111.6, 117.9, 118.3, 120.9, 122.2, 125.6, 127.0, 127.3, 129.4, 132.5, 136.7, 140.5, 143.5, 144.9, 155.1; FTIR (KBr) 3060, 2927, 2845, 1623, 1527, 1466, 1433, 1369, 1177 cm^{-1}; HRMS (*m/z*): $[M+H]^+$ calcd. for $C_{23}H_{21}N_2O_3S$: 405.1273; found: 405.1264.

10-Methyl-9-tosyl-9,10-dihydropyrido[3',2':4,5]pyrrolo[2,3-*b*]indole (4g): White solid, mp 160-162 °C; R_f 0.46 (20% ethyl acetate in hexanes); ^{1}H NMR ($CDCl_3$, 400 MHz) δ 2.21 (s, 3H), 4.33 (s, 3H), 6.98 (d, *J*=8.4 Hz, 2H), 7.20(dd, *J*=7.6 Hz, 1H), 7.22-7.27 (m, 1H), 7.31 (t, *J*=8.4 Hz, 1H), 7.39 (d, *J*=8.4 Hz, 2H), 7.58 (d, *J*=7.6 Hz, 1H), 8.05 (dd, *J*=7.6, 0.8 Hz, 1H), 8.22 (d, *J*=8.4 Hz, 1H), 8.40 (dd, *J*=4.8, 1.2 Hz, 1H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 21.6, 32.5, 106.1, 113.9, 117.0, 117.6, 118.5, 122.9, 125.6, 126.6, 126.9, 127.0, 129.6, 132.9, 139.9, 142.4, 145.2, 151.5; FTIR (KBr) 3056, 2926, 1609, 1514, 1435 cm^{-1}; HRMS (*m/z*): $[M+H]^+$ calcd. for $C_{21}H_{12}N_3O_2S$: 376.1120; found: 376.1131.

5-Methyl-6-tosyl-5,6-dihydroindolo[2,3-*b*]indole-2-carbonitrile (4h): White solid, mp 223-225 °C; R_f 0.43 (20% ethyl acetate in hexanes); ^{1}H NMR ($CDCl_3$, 400 MHz ppm) δ 2.13 (s, 3H), 4.16 (s, 3H), 6.89 (d, *J*=8 Hz, 2H), 7.15-7.28 (m, 4H), 7.42-7.52 (m, 3H), 8.00 (s, 1H), 8.08 (d, *J*=8Hz, 1H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 21.7, 34.4, 104.2, 109.2, 111.7, 118.0, 118.9, 120.2, 120.5, 124.5, 125.4, 126.0, 126.2, 127.0, 129.6, 132.4, 140.8, 143.0, 144.2, 145.5; FTIR (KBr) 2923, 2855, 2217, 1614, 1515, 1466, 1439, 1169 cm^{-1}.

6-Methyl-5-tosyl-6,11-dihydro-5H-indolo[2,3-*b*]quinoline (4i): Pale red solid, mp 97-99 °C; R_f 0.46 (10% ethyl acetate in hexanes); ^{1}H NMR ($CDCl_3$, 400 MHz) δ 2.21 (d, *J*=18.6 Hz, 1H), 2.27 (s, 3H), 3.41 (d, *J*=18.6 Hz, 1H), 3.86 (s, 3H), 6.89 (s, 3H), 6.93 (d, *J*=8.4 Hz, 1H), 7.03 (dt, *J*=7.2, 0.8 Hz, 1H), 7.11 (dt, *J*=7.6, 1.2 Hz, 1H), 7.15-7.25 (m, 2h), 7.28 (d, *J*=8.4 Hz, 1H), 7.32 (dd, *J*=7.6, 0.8 Hz, 1H), 7.77 (dd, *J*=8, 1.2 Hz, 1H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 21.8, 25.3, 30.8, 106.2, 110.0, 118.2, 119.6, 122.1, 124.1, 126.6, 127.3, 128.2, 128.7, 128.9, 129.1, 131.7, 133.5, 136.3, 136.4, 138.2, 144.8; FTIR (KBr) 3054, 2925, 2855, 1636, 1608, 1516, 1483, 1428 cm^{-1}; HRMS (*m/z*): $[M+H]^+$ calcd. for $C_{23}H_{21}N_2O_2S$: 389.1324; found: 389.1327.

9-bromo-6-methyl-5-tosyl-6,11-dihydro-5H-indolo[2,3-b]quinoline (4j): White solid, mp 154-156 °C; R_f 0.52 (10% ethyl acetate in hexanes); ^{1}H NMR ($CDCl_3$, 400 MHz, ppm) δ 2.23 (d, *J*=18.4 Hz, 1H), 2.38 (s, 3H), 3.44 (d, *J*=18.4 Hz, 1H),

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DOI: 10.1039/C5OB02440H

3.93 (s, 3H), 6.93 (d, *J*= 8.4 Hz, 2H), 7.02 (d, *J*=8.0 Hz, 3H), 7.21-7.26 (m, 2H), 7.30-7.36 (m, 2H), 7.53 (d, *J*=0.8 Hz, 1H), 7.85 (dd, *J*= 8, 0.8 Hz, 1H); ^{13}C NMR ($CDCl_3$, 100 MHz, ppm) δ 21.8, 25.1, 31.0, 105.8, 111.6, 112.9, 120.8, 124.9, 125.6, 126.3, 126.8, 127.5, 128.2, 128.7, 128.8, 129.3, 131.5, 135.0, 135.9, 138.0, 145.1; FTIR (KBr) 3060, 2953, 2853, 1606, 1596, 1567, 1491, 1468, 1362, 1280 cm^{-1}. HRMS (*m/z*): $[M+Na]^+$ calcd. for $C_{23}H_{19}N_2O_2NaSBr$: 489.0248; found:489.0219 (HRMS data for ^{79}Br isotope).

General procedure for C2 amidative cyclization followed by detosylation and aromatization: Indole derivative **3f-i** (0.5 mmol) was taken in a clean and dry reaction tube. To this iodine (0.6 mmol), Cs_2CO_3 (1.0 mmol) and acetonotrile (2 mL) were added. The reaction tube was stoppered and the resulting reaction mixture was stirred at 60 °C. After 4 h the second portion of iodine (0.3 mmol) was added and reaction is allowed to stir at 60 °C. Upon completion of reaction as monitored by TLC, solvent was removed under vacuum in rotary evaporator and DCM was added. The crude reaction mixture was washed with saturated $Na_2S_2O_3$ solution (2 × 10 mL) and extracted with DCM. The organic layer was washed with water (1 × 10 mL). Combined organic layers were concentrated using rotary evaporator and residue is purified by column chromatography on silica gel using hexanes/ethyl acetate as an eluent to afford pure product **5a-d**.

6-Methyl-6H-indolo[2,3-*b*]quinoline (5a): Pale yellow solid, mp 83-87 °C; R_f 0.42 (10% ethyl acetate in hexanes); ^{1}H NMR ($CDCl_3$, 500 MHz) δ 4.02 (s, 3H), 7.32 (d, *J*=7.2 Hz, 1H), 7.41 (d, *J*=8 Hz, 1H), 7.47 (dt, *J*=7, 1 Hz, 1H), 7.57-7.62 (m, 1H), 7.71-7.76 (m, 1H), 8.00 (d, *J*=8 Hz, 1H), 8.14 (d, *J*=7.5 Hz, 1H), 8.22 (d, *J*=8.5 Hz, 1H), 8.70 (s, 1H) ; ^{13}C NMR ($CDCl_3$, 125 MHz) δ 28.2, 109.0, 118.6, 120.4, 120.4, 121.6, 123.3, 124.0, 127.0, 128.1, 128.4, 128.7, 129.4, 142.9, 146.0, 152.3; FTIR (KBr) 3053, 2928, 1607, 1579, 1483, 1430 cm^{-1}.

9-bromo-6-methyl-6H-indolo[2,3-*b*]quinoline (5b): Yellow solid, mp 132-134 °C; R_f 0.46 (20% ethyl acetate in hexanes); ^{1}H NMR ($CDCl_3$, 400 MHz, ppm) δ 3.86 (s, 3H), 7.07 (1:1 q, *J*=7.2 Hz, 1H), 7.14-7.19 (m, 1H), 7.39 (t, *J*= 7.2 Hz, 1H), 7.56 (dd, *J*= 8.4, 2.4 Hz, 1H), 7.65 (dt, *J*= 7.6, 1.2 Hz, 1H), 7.89 (d, *J*= 8.0 Hz, 1H), 8.07 (d, *J*=8.8 Hz, 1H), 8.11 (s, 1H), 8.52 (s, 1H); ^{13}C NMR ($CDCl_3$, 100 MHz, ppm) δ 28.1, 110.3, 112.9, 117.2, 122.2, 123.5, 124.1, 124.3, 127.4, 127.8, 128.2, 128.4, 128.8, 129.6, 130.9, 141.5; FTIR (KBr) 2923, 2852, 1603, 1572, 1477, 1458, 1325, 1254 cm^{-1}. HRMS (*m/z*): $[M+H]^+$ calcd. for $C_{16}H_{12}N_2Br$: 311.0184; found:311.0172 (HRMS data for ^{79}Br isotope).

9-Methoxy-6-methyl-6H-indolo[2,3-*b*]quinoline (5c): Yellow solid, mp 110-112 °C; R_f 0.46 (20% ethyl acetate in hexanes); ^{1}H NMR ($CDCl_3$, 400 MHz) δ 3.95 (s, 3H), 3.96 (s, 3H), 7.20 (dd, *J*=8.6, 2.4 Hz, 1H), 7.31 (d, *J*=8.8 Hz, 1H), 7.44 (dd, *J*=7.4, 1.2 Hz, 1H), 7.66 (d, *J*=2.4 Hz, 1H), 7.71 (dt, *J*=7.6, 1.6 Hz, 1H), 7.98 (dd, *J*=8.4, 1.2 Hz, 1H), 8.15 (d, *J*=8.4 Hz, 1H), 8.66 (s, 1H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 28.0, 56.3, 105.7, 109.5, 116.3, 118.5, 120.9, 122.9, 123.9, 127.4, 127.7, 127.8, 128.3, 128.7, 129.1, 137.7, 154.5; FTIR (KBr) 3055, 2927, 2855, 1615, 1576, 1392, 1285 cm^{-1}.

6-ethyl-6H-indolo[2,3-*b*]quinoline (5d): White solid, mp 93-95 °C; R_f 0.56 (10% ethyl acetate in hexanes); ^{1}H NMR ($CDCl_3$, 500 MHz, ppm) δ 1.52 (t, *J*=7.2 Hz, 3H), 4.61 (q, *J*=7.2 Hz, 2H), 7.30 (dt, *J*= 7.2, 0.8 Hz, 1H), 7.42-7.49 (m, 2H), 7.58 (dt, *J*= 7.6, 1.2 Hz, 1H), 7.73 (dt, *J*= 7.6, 1.6 Hz, 1H), 8.00 (dd, *J*= 8.2, 1.6 Hz, 1H), 8.17 (t, *J*= 8.4 Hz, 2H), 8.71 (s, 1H) ; ^{13}C NMR ($CDCl_3$, 125 MHz, ppm) δ 13.8, 36.4, 109.0, 118.5, 120.0, 120.7, 121.7, 123.0, 124.2, 127.5, 127.8, 128.2, 128.6, 129.0, 142.0, 146.7, 152.1; FTIR (KBr) 3056, 2926, 2853, 1605, 1571, 1481, 1450, 1349, 1229 cm^{-1}.

6-Isopropyl-6H-indolo[2,3-*b*]quinoline (5e): Pale yellow solid, mp 83-87 °C; R_f 0.42 (10% ethyl acetate in hexanes); ^{1}H NMR ($CDCl_3$, 500 MHz) δ 1.66 (d, *J*=7.0 Hz, 6H), 5.56 (septet, *J*=7.0 Hz, 1H), 7.17 (t, *J*=7.5 Hz, 1H), 7.34 (t, *J*=8 Hz, 1H), 7.43 (t, *J*=7.5 Hz, 1H), 7.49 (d, *J*=8.5 Hz, 1H), 7.60 (t, *J*=7.5 Hz, 1H), 7.88 (d, *J*=8.5 Hz, 1H), 8.02 (d, *J*=8.5 Hz, 1H), 8.59 (s, 1H); ^{13}C NMR ($CDCl_3$, 125 MHz) δ 21.0, 44.9, 110.7, 118.3, 119.5, 121.1, 121.5, 122.7, 124.1, 127.0, 127.2, 127.6, 128.3, 128.7, 141.3, 146.8, 152.3; FTIR (KBr) 3058, 2969, 2854, 1604, 1569, 1461, 1365, 1234 cm^{-1}.

General procedure for iodine mediated intramolecular competitive experiment:

Compound **6a** (0.5 mmol) was taken in a clean and dry reaction tube. To this iodine (0.6 mmol), Cs_2CO_3 (1.0 mmol) and acetonotrile (2 mL) were added. The reaction tube was stoppered and the resulting reaction mixture was stirred at 60 °C. After 4 h the second portion of iodine (0.3 mmol) was added and reaction is allowed to stir at 60 °C. Upon completion of reaction as monitored by TLC, solvent was removed under vacuum in rotary evaporator and DCM was added. The crude reaction mixture was washed with saturated $Na_2S_2O_3$ solution (2 × 10 mL) and extracted with DCM. The organic layer was washed with water (1 × 10 mL). Combined organic layers were concentrated using rotary evaporator and residue is purified by column chromatography on silica gel using hexanes/ethyl acetate as an eluent to afford pure products **7a** and **7b**.

14,15-ditosyl-15H-benzo[4,5]imidazo[1,2-*a*]indolo[2,3-*b*]indol-(14H)-ol (7a): White solid, mp 198-200 °C; R_f 0.41 (20% ethyl acetate in hexanes); ^{1}H NMR ($CDCl_3$, 500 MHz, ppm) δ 2.21 (s, 3H), 2.45 (s, 3H), 6.61 (d, *J*=7.6 Hz, 1H), 6.93 (d, *J*=8 Hz, 2H), 6.96 (dd, *J*=7.4, 1.2 Hz, 1H), 7.02 (dt, *J*=7.6, 1.6 Hz, 1H), 7.07-7.10 (m, 2H), 7.27 (d, *J*=8.0 Hz, 3H), 7.39 (d, *J*=8 Hz, 4H), 7.71 (dd, *J*=8, 1.6 Hz, 1H), 7.77 (dd, *J*=7.6, 1.2 Hz, 1H), 7.83 (d, *J*=8.0 Hz, 1H), 7.87 (d, *J*=8.8 Hz, 2H); ^{13}C NMR ($CDCl_3$, 125 MHz, ppm) δ 21.4, 21.9, 87.5, 110.8, 111.9, 113.6, 113.7, 123.2, 123.4, 123.7, 124.6, 125.1, 125.3, 126.1, 128.0, 129.0, 129.8, 129.9, 132.6, 132.8, 134.4, 135.3, 138.9, 141.3, 143.5, 144.4, 145.2; FTIR (KBr) 3061, 2923, 2857, 1597, 1487, 1169 cm^{-1}.

2-(6-tosylindolo[2,3-b]indol-5(6H)-yl)aniline (7b): Pale yellow solid, mp 105-107 °C; R_f 0.56 (20% ethyl acetate in hexanes); ^{1}H NMR ($CDCl_3$, 500 MHz, ppm) δ 2.24 (s, 3H), 6.89 (t, *J*=7.6 Hz, 1H), 7.12-7.20 (m, 2H), 7.23-7.27 (m, 1H), 7.28-7.32 (m, 2H), 7.33-7.40 (m, 2H), 7.46 (d, *J*=8.4 Hz, 2H), 7.76 (d, *J*= 7.2 Hz, 1H), 7.89 (d, *J*=7.6 Hz, 1H), 8.21 (d, *J*= 8.0 Hz, 1H); ^{13}C NMR ($CDCl_3$, 125 MHz, ppm) δ 21.6, 112.4, 116.8, 116.9, 118.8, 118.9, 119.3, 120.9, 121.9, 122.8, 122.8, 125.1, 126.0, 127.1, 129.1, 129.5, 129.8, 134.0, 139.9, 141.6, 141.7, 143.9, 144.9;

FTIR (KBr) 3472, 3382, 3056, 2925, 2857, 1615, 1509, 1456, 1375, 1262 cm^{-1}.

Acknowledgements

We thank DST (SB/S1/OC-72/2013) for funding. V.R. thanks DST for funding fast track project (Project No. SB/FT/CS-167/2013). B.S. thanks UGC, New Delhi for SRF. We thank IIT-Madras for infrastructure facilties.

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