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PAPER

An alternative one-pot gold-catalyzed approach to the assembly of 11*H*-indolo-[3,2-*c*]quinolines†

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A new one-pot approach was developed to construct the 11*H*-indolo[3,2-*c*]quinoline scaffold through a gold-catalysed reaction of 2-[(2-aminophenyl)ethynyl]phenylamine derivatives with aldehydes. The broad scope and the high regioselectivity of this new protocol as well as the mild and neutral reaction conditions make it a viable alternative to the previously reported procedures.

Introduction

Indole derivatives represent privileged structures because of their role as bioactive natural products and their importance in other research areas relevant for life such as agrochemistry or materials science.[1] In particular, some fused indole derivatives containing the indolo[3,2-*c*]quinoline scaffold are naturally occurring alkaloids which have attracted considerable attention for the development of a new class of drug leads.[2] Isocryptolepine (5-methyl-5*H*-indolo[3,2-*c*]quinoline), extracted from the African medicinal plant Cryptolepis sanguinolenta, and isoneocryptolepine (Fig. 1), which has never been found in nature, have been evaluated for their broad spectrum of biological activities including antiparasitic, antifungal, antibacterial, cytotoxic, anti-inflammatory and antihyperglycemic.

As a consequence, to further investigate the structure–activity relationship, a variety of synthetic strategies based on indole and quinoline formation have been developed.[3]

Recently, to overcome some drawbacks due to the lacking of flexibility of previous methodologies with respect to the introduction of different substituents, Wang designed a strategy to assemble 11*H*-indolo[3,2-*c*]quinolines by the two-step protocol.[4] The five- and six-membered nitrogen-containing rings in the tetracyclic skeleton were elaborated through a gold(III)-catalysed

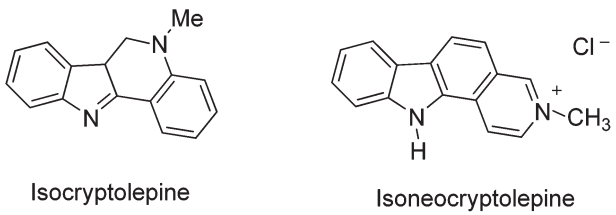
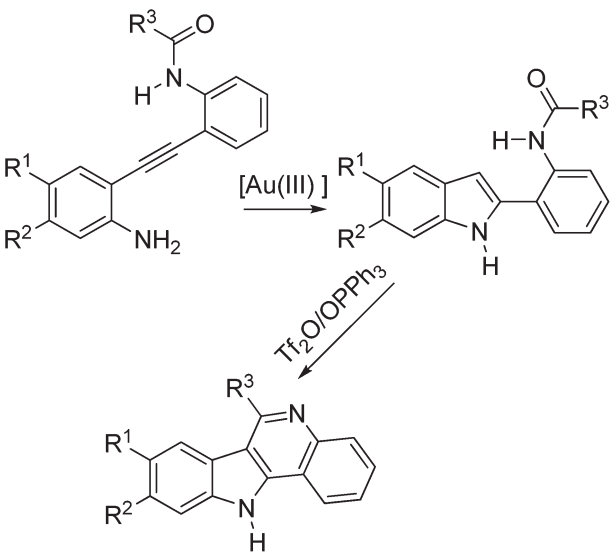


Fig. 1 Indolo[3,2-*c*]quinoline scaffolds.



Scheme 1

5-*endo-dig* cyclization and Hendrickson reagent promoted regioselective 6-*endo*-cyclization (Scheme 1).

The straightforward palladium-catalysed carbonylative cyclization reaction of *o*-(*o*-aminophenyl)trifluoroacetanilide with aryl iodides followed by subsequent intramolecular condensation

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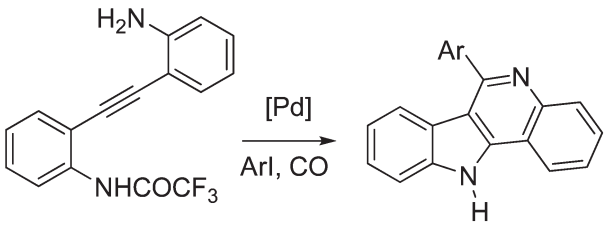
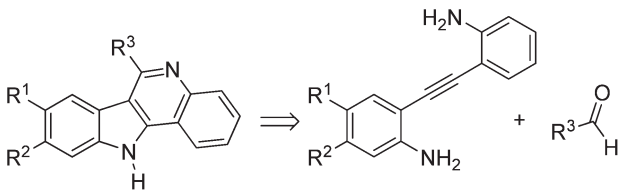
† Electronic supplementary information (ESI) available: Preparation and characterizations of compounds **1b–d** and **3a,c**; copies of the ^{1}H NMR and ^{13}C NMR for the new compounds. See DOI: 10.1039/c2ob26380g



Scheme 2



Scheme 3

of the resultant 3-acylindole accomplished an expedient approach to the construction of 6-arylated 11*H*-indolo[3,2-*c*]quinolines in a one-pot process (Scheme 2).[5]

Devising methods to construct target structures according to the concept of green and sustainable chemistry represents a major challenge for chemists in industry and academic institutions. The so-called "telescoping" of reactions[6] (the sequencing of multiple transformations in a single reaction vessel through the changing of conditions and/or adding of reagents at appropriate times) represents an attractive alternative to classical multistep synthesis for the easy assembly of readily available building blocks into more complex derivatives. Our continuing interest in the synthesis of indole derivatives by one-pot processes[7] led us to investigate a new approach to assemble 11*H*-indolo[3,2-*c*]quinolines with better flexibility according to the retrosynthetic Scheme 3.

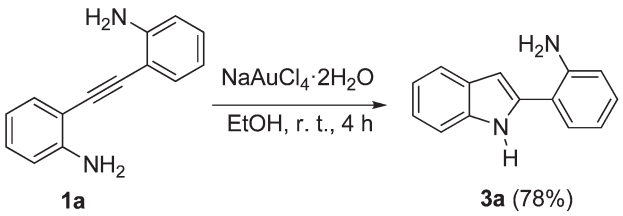
Here we wish to report the results of this study.

Results and discussion

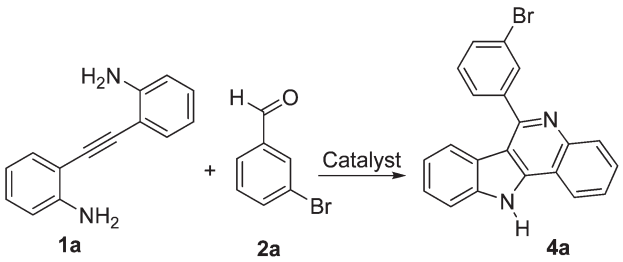
We selected the reaction of 2-[(2-aminophenyl)ethynyl]phenylamine **1a** with aldehydes in the presence of a gold catalyst[8] for initial studies. The alkyne **1a** was prepared through the palladium-catalysed cross-coupling of 2-ethynylaniline with 2-iodoaniline.[9] The efficient $NaAuCl_4{\cdot}2H_2O$ catalysed cyclization of 2-alkynyl-phenylamines to indoles in ethanol or ethanol–water mixtures at room temperature was previously investigated.[10] Accordingly, in a control experiment, the $NaAuCl_4{\cdot}2H_2O$ cyclization of the starting alkyne **1a** in ethanol was completed in 78% yield at room temperature (Scheme 4).

To explore the viability of the construction of the target indolo[3,2-*c*]quinoline skeleton according to our hypothesis, compound **1a** was reacted with 3-bromobenzaldehyde **2a** (Scheme 5).

Some results of our screening are summarized in Table 1. It was reported that a variety of gold-catalysed sequential cyclization/alkylation, *N*-alkylation/cyclization, or *N*-alkylation/cyclization/alkylation reactions of 2-alkynyl-phenylamine derivatives



Scheme 4



Scheme 5

Table 1 Screening of gold catalysts and reaction conditions

Entry	Catalyst (5 mol%)	Conditions [**1a**]/[**2a**] = 1 : 1	Time (h)	Product[a] **4a** (% yield)
1	$NaAuCl_4{\cdot}2H_2O$	Ethanol, 80 °C	22	27
2	$NaAuCl_4{\cdot}2H_2O$	CH_3CN, 80 °C	48	32
3	Ph_3PAuCl/AgOTf	CH_3CN, 80 °C	24	40
4	Ph_3PAuCl/AgOTf	CH_3CN, 100 °C	48	28
5	Ph_3PAuCl/AgOTf	DCE, 100 °C	48	28
6	AgOTf	DCE, 100 °C	48	35

[a] Yields refer to a single run and are for pure isolated products.

leading to different indoles can be directed by a suitable choice of the reaction conditions.[11] In particular, to avoid the competitive condensation reaction[12] the gold-catalysed domino cyclization/alkenylation of the 2-alkynylaniline derivative with 1,3-dicarbonyls was directed by increasing the reaction temperature.[13] Nevertheless, in the presence of $NaAuCl_4{\cdot}2H_2O$ (5 mol%) in ethanol at reflux (Table 1, entry 1), the 11*H*-indolo[3,2-*c*]-quinoline **3a** was isolated in only 27% yield.

Competitive simultaneously occurring reactions led to a complex mixture of by-products in which 6-(3-bromophenyl)-5,6-dihydroindolo[1,2-*c*]quinazoline **5a**, 6-(3-bromophenyl)-indolo[1,2-*c*]quinazoline **6a**, and 2-((2-aminophenyl)ethynyl)-*N*-benzylaniline **7a** (Fig. 2) were identified by MS-ESI and NMR analysis. In fact **5a** showed, besides other, the characteristic ^{13}C- and ^{1}H-NMR peaks at 67.7 ppm and 6.56 ppm, respectively, of the non-aromatic CH in the 1,2-dihydroquinazoline moiety.[14] Those peaks showed correlation in the 2D ^{13}C–^{1}H heterocorrelated spectrum. For **6a** the C2 in the quinazoline moiety gave a ^{13}C-NMR signal at 153.6 ppm in line with similar compounds.[15] Moreover, both, **5a** and **6a**, showed the ^{1}H and ^{13}C NMR signals for the CH of the heterocyclic indole moiety. In respect of **7a**, ^{13}C peaks at 91.0 and 91.8 ppm, for the ethynyl moiety, and at 47.2 ppm, characteristic of aminobenzyl CH_2, along with the correlation of the latter with the ^{1}H 4.39 ppm peak in the

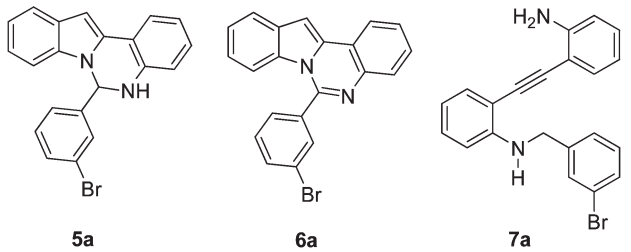
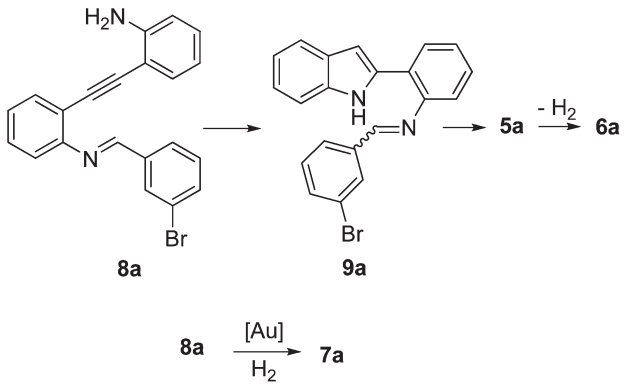


Fig. 2 By-products.



Scheme 6

^{13}C–^{1}H heterocorrelated spectrum, confirmed its nature. Overall, DEPT (Distortionless Enhancement by Polarization Transfer) experiments confirmed the supposed number of protons attached to each carbon.

Very likely,[16] the competitive condensation reaction between **1a** with 3-bromobenzaldehyde **2a** generates the 2-((2-aminophenyl)ethynyl)-*N*-(3-bromobenzilidene)aniline **8a** which can undergo the cyclization reaction to give the 5,6-dihydroindolo[1,2-*c*]quinazoline **5a**. The role of $NaAuCl_4{\cdot}2H_2O$ in promoting the condensation reaction of carbonyl derivatives with anilines has been previously reported.[17] Moreover, in previous studies we observed the high efficiency of gold(III) as both a Lewis acid/transition metal in sequential amination/annulation reactions of carbonyl derivative with amine.[18] The oxidation of **5a** to **6a** releases H_2 responsible for the catalytic transfer hydrogenation reaction[19] of **8a** to **7a** (Scheme 6). The formation of the 6-substituted indolo[1,2-*c*]quinazoline **6** after oxidative cyclization of intermediates **9** was previously reported in the literature.[20]

A slightly better yield of **4a** was observed in CH_3CN as the reaction medium (Table 2, entry 2). Participation of Au(I) in the sequential transformation of **1a** into the target indolo[3,2-*c*]quinoline suggested that the catalytic activity of Au(I) species might deserve advantages compared to Au(III) (Table 2, entry 3). Under $Ph_3PAuOTf$ catalysis the reaction of symmetrical diamines **1** with 4-pentyn-1-ol gave the corresponding indolo[3,2-*c*]quinolines through a process involving multiple catalytic cycles assisted by a single metal catalyst.[21] The Au(I) catalysis was, also, reported to be superior to that of Au(III) in the sequential cycloisomerization/C3-functionalization of 2-ethynylanilines with a wide range of aldehydes, isatins and nitrostyrenes.[22] Worsening of yield of **4a** was observed by elevating temperature at 100 °C (Table 1, entry 4). No advantage was derived by using DCE as a solvent instead of CH_3CN. A control experiment employing AgOTf as the sole catalyst under the same reaction conditions produced **4a** in 35% yield, but the selectivity of the process was unsatisfactory because of the simultaneous formation of **5a** (24% yield) and **6a** (8% yield). In contrast to classic Lewis acids, which are known to form strong σ-complexes, gold and silver derivatives can operate as bifunctional Lewis acids activating either (or both) carbon–carbon multiple bonds *via* π-bonding and/or forming σ-complexes by coordinating with heteroatoms.[23] Although the relative ability for making π- and σ-complexes of the catalyst with appropriate substrates is a valuable tool for addressing the desired transformations in the cases when bi- or polyfunctional substrates are involved,[24] the failure to selectively perform the domino process for the assembly of 11*H*-indolo[3,2-*c*]quinolines induced us to examine the one-pot combination of the gold-catalysed cyclization of 2-alkynylanilines followed by reaction with aldehyde (Scheme 7).

Application of the modified Pictet–Spenger reaction of heteroaryl-arylamines to the synthesis of fused six, seven, and eight-membered rings was successfully demonstrated.[25] The reaction of the key intermediate **3a** with aldehydes in the presence of trifluoroacetic acid furnished the corresponding indoloquinolines **4**.[26] Then we examined a variety of reaction conditions in order to optimize those more suitable for both steps of the process. When the 2,2′-(ethyne-1,2-diyl)dianiline **1a** was cyclised in CH_3CN at room temperature in the presence of PPh_3AuCl/AgOTf (5 mol%) and in the second step the aldehyde **2a** (2 equiv.) was added to the reaction mixture after 6 h (procedure A), the target **4a** was isolated in good overall yield after column chromatography (Table 2, entry 1). By replacing the PPh_3AuCl/AgOTf catalytic system with the stable Au(I)complex **A** (5 mol%) (Fig. 3),[27] the use of the silver co-catalyst (procedure B) was avoided and the first cyclization step was faster.

A number of aryl aldehydes were screened, and all were converted into the corresponding 6-arylated 11*H*-indolo[3,2-*c*]quinolines **4a–g** as expected (Table 2, entries 1–8). It seems that the electronic properties of the substituents on the aryl moiety of the starting aldehyde did not affect the outcome of the reaction. The presence of a substituent at the *o*-position on the aldehyde can be tolerated, but the assembly of the 11*H*-indolo[3,2-*c*]quinolines is hindered to some extent (Table 2, entry 5). The flexibility of our strategy was further established by generating 6-heteroarylated/6-alkylated derivatives (Table 2, entries 9–10). To further extend the scope, we prepared the 2-((2-aminophenyl)ethynyl)-polysubstituted-anilines **1b–d**. Interestingly, only the formation of the regioisomers **4k–l** was observed by reacting the 2-((2-aminophenyl)ethynyl)-4,6-dihaloanilines **1b–c** with **2g** according to procedure B (Scheme 8). The structures of **4k–l** were assigned on the basis of analytical and spectral data (see ESI†).

The 2-amino-3((2-aminophenyl)ethynyl)-5-nitrobenzonitrile **1d**, also, underwent under the reaction conditions the gold-catalyzed regioselective annulation to the corresponding 2-(2-aminophenyl)-5-nitro-1*H*-indole-7-carbonitrile **3d** in 64% yield, but we failed to observe the formation of the corresponding target 11*H*-indolo[3,2-*c*]quinoline derivative (Scheme 9).

Electronic effects could account for the observed results and gave an insight on the possible mechanism for the formation of the reaction products **4** under the present reaction conditions.

Table 2 Gold-catalysed synthesis of 11*H*-indolo[3,2-*c*]quinoline **4** from 2-[(2-aminophenyl)ethynyl]phenylamines **1** and aldehydes **2**

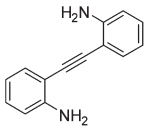
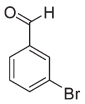
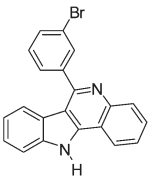
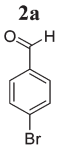
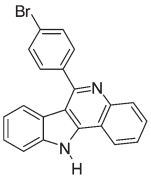
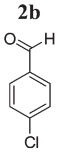
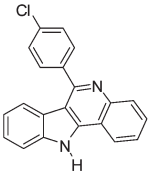
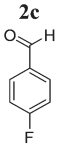
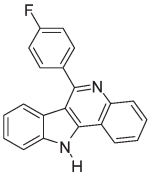
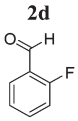
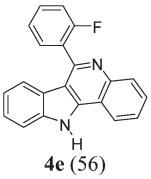
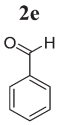
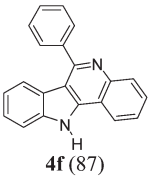
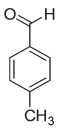
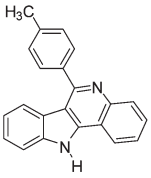
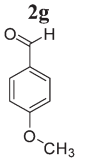
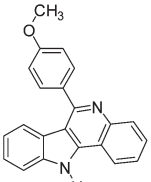
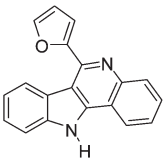
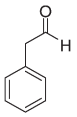
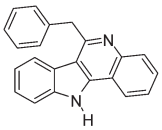
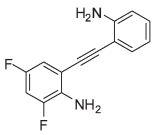
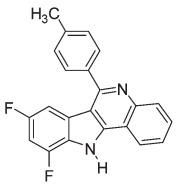
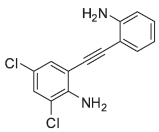
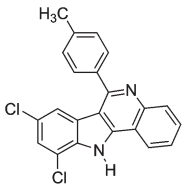
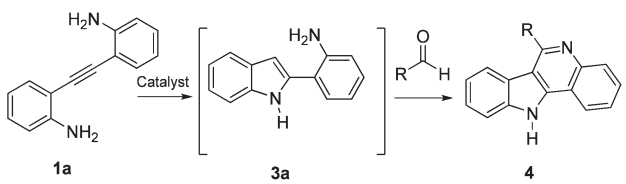
Entry	**1**	**2**	Procedure[a]	**4**[b]
1			A	 **4a** (78)
2	**1a**	**2a** 	B	 **4b** (93)
3	**1a**	**2b** 	A	 **4c** (90)
4	**1a**	**2c** 	B	 **4d** (74)
5	**1a**	**2d** 	B	 **4e** (56)
6	**1a**	**2e** 	A	 **4f** (87)
7	**1a**	**2f** 	B	 **4g** (80)
8	**1a**	**2g** 	A	 **4h** (78)

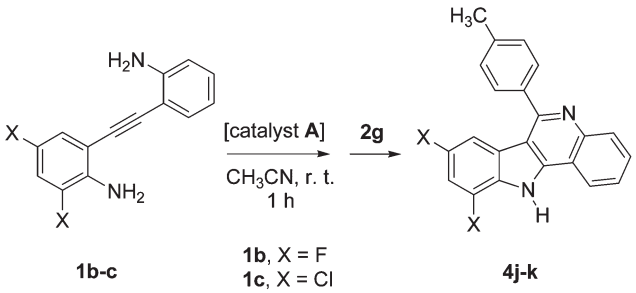
Table 2 *(Contd.)*

Entry	1	2	Procedure[a]	4[b]
9	**1a**	**2h** 	B	 **4i** (73)
10	**1a**	**2i**  **2j**	B	 **4j** (42)
11		**2g**	B	 **4k** (91)
12	**1b** 	**2g**	B	 **4l** (75)

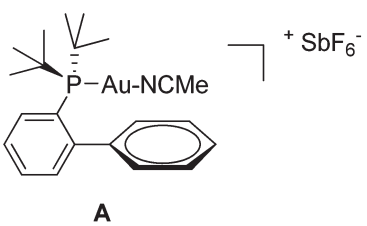
[a] *Procedure A*: the starting alkyne **1** was cyclised in CH_3CN at room temperature in the presence of $PPh_3AuCl/AgOTf$ (5 mol%). Then, the aldehyde **2a** (2 equiv.) was added to the reaction mixture. *Procedure B*: the starting alkyne **1** was cyclised in CH_3CN at room temperature in the presence of catalyst **A** (5 mol%). Then, the aldehyde **2a** (2 equiv.) was added to the reaction mixture. [b] Yields refer to a single run and are for pure isolated products.



Scheme 7



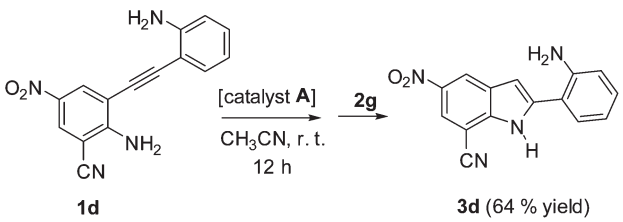
Scheme 8



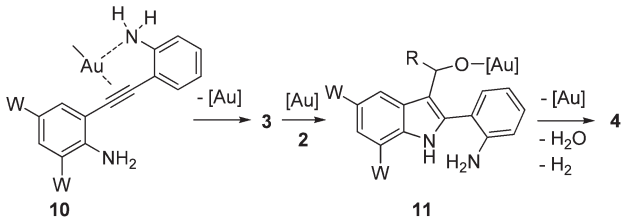
A

Fig. 3 Gold catalyst **A**.

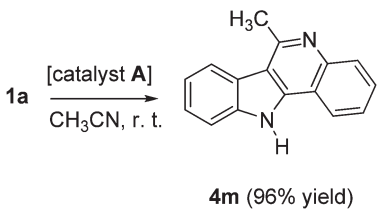
A reasonable mechanistic interpretation which also explains the regioselective formation of 11*H*-indolo[3,2-*c*]quinoline derivatives *versus* 6-substituted indolo[1,2-*c*]quinazolines might assume a reaction path that implies an initial π-coordination by a



Scheme 9



Scheme 10



Scheme 11

gold catalyst with the alkyne residue of starting substrate **1** to form a π complex **10**. The simultaneous nitrogen coordination of a gold catalyst in the complex **10** explains the regioselectivity of the cyclization step in the presence of electron withdrawing groups in one of the two aromatic rings of the starting alkyne derivatives **1**. Subsequent nucleophilic attack of the tethered free amino groups leads to ring closure to afford after proto-deauration cyclized indole **3**. The regenerated gold catalyst activates the carbonyl oxygen of the aldehyde and carries out an electrophilic addition reaction at C3 of the indole **3** to give the 3-substituted intermediate **11**. Finally, after loss of water and aromatization reactions the 11*H*-indolo[3,2-*c*]quinoline is generated (Scheme 10). The two strongly withdrawing substituents of the indole **3d** are responsible for the deactivation of the C3 position toward the electrophilic attack of the aldehyde **2g**.

Very surprisingly, the formation of the 6-methyl-11*H*-indolo-[3,2-*c*]quinoline **4m** can occur in excellent yield through a domino process involving CH_3CN as both the reacting partner and the reaction solvent (Scheme 11). The indolo[3,2-*c*]quinoline **4m** was isolated in traces in all the cases in which the gold-catalysed reaction of **1a** with aldehydes was carried out in CH_3CN as the reaction medium. Although CH_3CN starting from early publications was often used as a solvent because it was considered inert to gold catalysis,[28] nitriles σ- or π-bonded to gold complexes are more recently reported as key intermediates in a variety of synthetic applications.[29] Further studies of the scope and limitations of the synthesis of 11*H*-indolo[3,2-*c*]quinolines through gold-catalysed domino reactions of 2-[(2-aminophenyl)ethynyl]phenylamine derivatives with nitriles are under current investigation.

Conclusions

In summary, we have developed a new one-pot gold-catalysed approach to the assembly of 11*H*-indolo[3,2-*c*]quinolines from readily available unprotected 2-[2-(2-aminophenyl)ethynyl]anilines and aldehydes. The reaction scope is broad and a range of alkyne derivatives and aldehydes are allowed. The neutral and mild character of the applied conditions as well as the high regioselectivity for this protocol makes it a valuable alternative to those previously described in the literature. Most importantly, the possibility of nitrile activation by cationic gold complexes is of high relevance to develop a further versatile entry into the title compounds.

Experimental

General procedure A for the synthesis of 6-substituted-11*H*-indolo[3,2-*c*]quinolines 4

Ph_3AuCl (11.8 mg, 0.024 mmol) and AgOTf (6.2 mg, 0.024 mmol) were added to a solution of 2,2′-(ethyne-1,2-diyl)-dianiline derivative **1** (0.48 mmol). The mixture was stirred at r.t. and the reaction was monitored by TLC, following the disappearance of the starting material. Then, aldehyde **2** (0.96 mmol) was added and the mixture after stirring till completion was evaporated. Column chromatographic purification of the crude on silica gel (hexane–EtOAc) afforded the target 6-substituted-11*H*-indolo[3,2-*c*]quinoline **4**.

General procedure B for the synthesis of 6-substituted-11*H*-indolo[3,2-*c*]quinolines 4

Catalyst **A** (0.011 g, 0.014 mmol) was added to a solution of 2,2′-(ethyne-1,2-diyl)dianiline derivative **1** (0.29 mmol). The mixture was stirred at r.t. and the reaction was monitored by TLC, following the disappearance of the starting material. Then, aldehyde **2** (0.58 mmol) was added and the mixture after stirring till completion was evaporated. Column chromatographic purification of the crude on silica gel (hexane–EtOAc) afforded the target 6-substituted-11*H*-indolo[3,2-*c*]quinoline **4**.

6-(3-Bromophenyl)-11*H*-indolo[3,2-*c*]quinoline (4a). (0.140 g, 78% yield). Found C, 67.5; H, 3.7; N, 7.5. Calcd for $C_{21}H_{13}BrN_2$: C, 67.6; H, 3.5; N, 7.5. IR (KBr): ν_{max}/cm^{-1} 3434, 2969, 1557, 1509, 743. δ_H (400 MHz; DMSO; Me_4Si) 7.17 (1H, ddd, J = 8.1 Hz, J = 7.1 Hz, J = 0.9 Hz), 7.46 (1H, ddd, J = 8.1 Hz, J = 7.1 Hz, J = 1.2 Hz), 7.53 (1H, d, J = 8.0 Hz), 7.60 (1H, t, J = 7.8 Hz), 7.69–7.82 (4H, m), 7.86 (1H, dt, J = 7.6 Hz, J = 1.2 Hz), 8.05 (1H, t, J = 1.7 Hz), 8.15 (1H, d, J = 8.0 Hz), 8.60 (1H, d, J = 7.8 Hz), 12.94 (1H, s, N*H*). δ_C (100.6 MHz; DMSO; Me_4Si) 111.8 (C), 112.1 (CH), 116.3 (C), 120.4 (CH), 120.8 (CH), 121.4 (C), 121.7 (C), 122.0 (CH), 125.5 (CH), 125.8 (CH), 127.9 (CH), 128.6 (CH), 129.4 (CH), 130.5 (CH), 131.5 (CH), 131.6 (CH), 135.4 (C), 139.1 (C), 142.9 (C), 144.8 (C), 153.6 (C). MS-ESI: *m*/*z*: 375 (M^+ ^{81}Br + H, 96%), 373 (M^+ ^{79}Br + H, 100).

6-(4-Bromophenyl)-11*H*-indolo[3,2-*c*]quinoline (4b). (0.101 g, 93%). Found C, 67.5; H, 3.5; N, 7.4. Calcd for $C_{21}H_{13}BrN_2$: C, 67.6; H, 3.5; N, 7.5. IR (KBr): ν_{max}/cm^{-1} 2924.78, 1586.26, 1512.12, 743.62. δ_H (400 MHz; DMSO; Me_4Si) 7.17 (1H, ddd, J = 8.1 Hz, J = 7.1 Hz, J = 1.1 Hz), 7.46 (1H, ddd, J = 8.2 Hz, J = 7.1 Hz, J = 1.2 Hz), 7.53 (1H, d, J = 8.2 Hz), 7.68–7.86 (7H, m), 8.12 (1H, ddd, J = 8.3 Hz, J = 1.4 Hz, J = 0.6 Hz), 8.57 (1H, ddd, J = 8.1 Hz, J = 1.6 Hz, J = 0.7 Hz), 12.93 (1H, s, N*H*). δ_C (100.6 MHz; DMSO; Me_4Si) 112.2 (C), 112.5 (CH),

116.7 (CH), 120.9 (CH), 121.4 (C), 121.9 (CH), 122.4 (C), 122.8 (CH), 125.9 (CH), 126.3 (CH), 129.1 (CH), 129.9 (C), 131.5 (2 × CH), 131.9 (2 × CH), 139.5 (C), 140.4 (C), 141.6 (C), 145.4 (C), 154.6 (C). MS-ESI: *m*/*z*: 375 (M^+ ^{81}Br + H, 96%), 373 (M^+ ^{79}Br + H, 100).

6-(4-Chlorophenyl)-11*H*-indolo[3,2-*c*]quinoline (4c). (0.142 g, 90%). Found C, 76.65; H, 3.9; N, 8.45. Calcd for $C_{21}H_{13}ClN_2$: C, 76.7; H, 4.0; N, 8.5. IR (KBr): ν_{max}/cm^{-1} 2920.14, 1558.80, 1512.21, 746.24. δ_H (400 MHz; DMSO; Me_4Si) 7.17 (1H, ddd, *J* = 8.1 Hz, *J* = 7.1 Hz, *J* = 1.1 Hz), 7.46 (1H, ddd, *J* = 8.2 Hz, *J* = 7.1 Hz, *J* = 1.2 Hz), 7.53 (1H, d, *J* = 8.2 Hz), 7.69–7.72 (3H, m), 7.73 (1H, dt, *J* = 8.1 Hz, *J* = 1.0 Hz), 7.77 (1H, ddd, *J* = 8.3 Hz, *J* = 6.9 Hz, *J* = 1.6 Hz), 7.86–7.88 (2H, m), 8.13 (1H, ddd, *J* = 8.3 Hz, *J* = 1.4 Hz, *J* = 0.6 Hz), 8.60 (1H, ddd, *J* = 8.1 Hz, *J* = 1.6 Hz, *J* = 0.6 Hz), 12.91 (1H, s, N*H*). δ_C (100.6 MHz; DMSO; Me_4Si) 111.7 (C), 112.0 (CH), 116.2 (CH), 120.4 (CH), 120.9 (CH), 121.4 (C), 121.9 (CH), 125.4 (CH), 125.8 (CH), 128.48 (2 × CH), 128.54 (C), 129.4 (2 × CH), 130.7 (CH), 133.6 (C), 139.0 (C), 139.5 (C), 141.0 (C), 144.9 (C), 154.1 (C). MS-ESI: *m*/*z*: 331 (M^+ ^{37}Cl + H, 37%), 329 (M^+ ^{35}Cl + H, 100).

6-(4-Fluorophenyl)-11*H*-indolo[3,2-*c*]quinoline (4d). (0.063 g, 74%). Found C, 80.7; H, 4.15; N, 8.9. Calcd for $C_{21}H_{13}FN_2$: C, 80.75; H, 4.2; N, 9.0. IR (KBr): ν_{max}/cm^{-1} 3320.90, 1562.30, 1503.82, 746.36. δ_H (400 MHz; DMSO; Me_4Si) 7.16 (1H, ddd, *J* = 8.1 Hz, *J* = 7.1 Hz, *J* = 1.1 Hz), 7.43–7.49 (3H, m), 7.53 (1H, dt, *J* = 8.1 Hz, *J* = 1.9 Hz), 7.68–7.79 (3H, m), 7.87–7.91 (2H, m), 8.13 (1H, ddd, *J* = 8.3 Hz, *J* = 1.4 Hz, *J* = 0.6 Hz), 8.58 (1H, ddd, *J* = 8.3 Hz, *J* = 1.4 Hz, *J* = 0.6 Hz), 12.92 (1H, s, N*H*). δ_C (100.6 MHz; DMSO; Me_4Si) 111.9 (C), 112.0 (CH), 115.3 (d, ^2J = 21.5 Hz, 2 × CH), 116.3 (C), 120.4 (CH), 120.9 (CH), 121.6 (C), 121.9 (CH), 125.4 (CH), 125.7 (CH), 128.5 (CH), 129.3 (CH), 131.1 (d, ^3J = 8.3 Hz, 2 × CH), 137.1 (d, ^4J = 2.4 Hz, C), 139.1 (C), 141.1 (C), 144.9 (C), 154.4 (C), 162.6 (d, ^1J = 245.5 Hz, C). MS-ESI: *m*/*z*: 313 (M − H^+, 100%).

6-(2-Fluorophenyl)-11*H*-indolo[3,2-*c*]quinoline (4e). (0.050 g, 56%). Found C, 80.7; H, 4.1; N, 8.9. Calcd for $C_{21}H_{13}FN_2$: C, 80.75; H, 4.2; N, 9.0. IR (KBr): ν_{max}/cm^{-1} 3421.03, 1649.25, 727.32. δ_H (400 MHz; DMSO; Me_4Si) 7.12–7.16 (1H, m), 7.18–7.20 (1H, m), 7.42–7.45 (1H, m), 7.46 (1H, dd, *J* = 2.5 Hz, *J* = 1.2 Hz), 7.48–7.51 (1H, m), 7.65–7.76 (4H, m), 7.77–7.81 (1H, m), 8.17 (1H, d, *J* = 8.1 Hz), 8.61 (1H, dd, *J* = 7.9 Hz, *J* = 1.4 Hz), 12.94 (1H, s, N*H*). δ_C (100.6 MHz; DMSO; Me_4Si) 112.0 (CH), 113.1 (C), 115.8 (d, ^2J = 21.3 Hz, CH), 116.5 (C), 120.2 (CH), 120.5 (CH), 121.5 (C), 122.0 (CH), 124.8 (d, ^4J = 2.5 Hz, CH), 125.5 (CH), 125.9 (CH), 128.5 (CH), 129.4 (CH), 131.0 (d, ^3J = 8.0 Hz, CH), 131.2 (d, ^3J = 2.7 Hz, CH), 134.5 (C), 139.0 (C), 140.4 (C), 144.9 (C), 150.0 (C), 159.5 (d, ^1J = 245.7 Hz, C); MS-ESI: *m*/*z*: 313 (M − H^+, 100%).

6-(4-Methylphenyl)-11*H*-indolo[3,2-*c*]quinoline (4g). (0.071 g, 80%). Found C, 80.6; H, 5.15; N, 9.15. Calcd for $C_{22}H_{16}N_2$: C, 80.7; H, 5.2; N, 9.1. IR (KBr): ν_{max}/cm^{-1} 1620.32, 740.05. δ_H (400 MHz; DMSO; Me_4Si) 2.49 (3H, s, CH_3), 7.15 (1H, t, *J* = 7.6 Hz), 7.44–7.47 (3H, m), 7.57 (1H, d, *J* = 8.1 Hz), 7.68–7.79 (5H, m), 8.13 (1H, d, *J* = 8.4 Hz), 8.58 (1H, d, *J* = 8.0 Hz), 12.92 (1H, s, N*H*). δ_C (100.6 MHz; DMSO; Me_4Si) 21.0 (*C*H$_3$), 111.86 (CH), 111.89 (C), 116.1 (C), 120.2 (CH), 121.0 (CH), 121.7 (C), 121.9 (CH), 125.3 (CH), 125.5 (CH), 128.5 (CH), 128.8 (2 × CH), 128.9 (2 × CH), 129.0 (CH), 137.5 (C), 138.3 (C), 139.0 (C), 141.0 (C), 144.6 (C), 155.3 (C). MS-ESI: *m*/*z*: 309 (M − H^+, 100%).

6-(2-Furyl)-11*H*-indolo[3,2-*c*]quinoline (4i). (0.060 g, 73%). Found C, 80.3; H, 4.2; N, 9. 8. Calcd for $C_{19}H_{12}N_2O$: C, 80.3; H, 4.25; N, 9.85. IR (KBr): ν_{max}/cm^{-1} 3400.80, 1556.19, 1502.60, 764.35. δ_H (400 MHz; DMSO; Me_4Si) 6.87–6.88 (1H, m), 7.36 (1H, t, *J* = 7.5 Hz), 7.38–7.39 (1H, m), 7.55 (1H, t, *J* = 7.6 Hz), 7.71 (1H, t, *J* = 7.5 Hz), 7.77–7.81 (2H, m), 8.15 (1H, d, *J* = 8.4 Hz), 8.17 (1H, s), 8.52 (1H, d, *J* = 8.2 Hz), 8.59 (1H, d, *J* = 8.0 Hz), 12.97 (1H, s, N*H*). δ_C (100.6 MHz; DMSO; Me_4Si) 110.9 (C), 111.5 (CH), 111.8 (CH), 112.3 (CH), 116.2 (C), 120.6 (CH), 121.3 (C), 121.9 (CH), 122.8 (CH), 125.6 (CH), 125.7 (CH), 128.7 (CH), 128.9 (CH), 139.2 (C), 141.5 (C), 144.0 (CH), 144.3 (C), 144.4 (C), 153.8 (C). MS-ESI: *m*/*z*: 285 (M − H^+, 100%).

6-Benzyl-11*H*-indolo[3,2-*c*]quinoline (4j). (0.037 g, 42%). Found C, 85.6; H, 5.4; N, 9.0. Calcd for $C_{22}H_{16}N_2$: C, 85.7; H, 5.2; N, 9.1. IR (KBr): ν_{max}/cm^{-1} 3397.90, 1667.11, 1563.21, 748.60. δ_H (400 MHz; DMSO; Me_4Si) 4.83 (2H, s, CH_2), 7.15 (1H, dt, *J* = 7.3 Hz, *J* = 1.4 Hz), 7.21–7.27 (2H, m), 7.29 (1H, ddd, *J* = 8.1 Hz, *J* = 7.2 Hz, *J* = 1.1 Hz), 7.31–7.34 (2H, m), 7.48 (1H, ddd, *J* = 8.2 Hz, *J* = 7.2 Hz, *J* = 1.1 Hz), 7.69 (1H, ddd, *J* = 8.31 Hz, *J* = 6.9 Hz, *J* = 1.2 Hz), 7.72–7.75 (1H, m), 7.77 (1H, ddd, *J* = 8.4 Hz, *J* = 6.9 Hz, *J* = 1.5 Hz), 8.14 (1H, ddd, *J* = 8.3 Hz, *J* = 1.2 Hz, *J* = 0.4 Hz), 8.15 (1H, ddd, *J* = 8.1 Hz, *J* = 1.1 Hz, *J* = 0.8 Hz), 8.58 (1H, ddd, *J* = 8.1 Hz, *J* = 1.6 Hz, *J* = 0.5 Hz), 12.99 (1H, s, N*H*). δ_C (100.6 MHz; DMSO; Me_4Si) 42.2 (*C*H$_2$), 111.9 (CH), 112.8 (C), 116.1 (C), 120.7 (CH), 121.5 (C), 121.6 (CH), 122.0 (CH), 125.2 (CH), 125.4 (CH), 126.1 (CH), 128.2 (CH), 128.31 (2 × CH), 128.35 (2 × CH), 128.42 (CH), 138.4 (C), 138.9 (C), 140.9 (C), 144.1 (C), 155.4 (C). MS-ESI: *m*/*z*: 309 (M − H^+, 100%).

8,10-Difluoro-6-(4-methylphenyl)-11*H*-indolo[3,2-*c*]quinoline (4k). (0.091 g, 91%). Found C, 76.7; H, 4.2; N, 8.1. Calcd for $C_{22}H_{14}F_2N_2$: C, 76.7; H, 4.1; N, 8.1. IR (KBr): ν_{max}/cm^{-1} 3421.03, 1649.25, 1503.92, 757.22. δ_H (400 MHz; DMSO; Me_4Si) 2.50 (3H, s, CH_3), 7.00 (1H, dd, *J* = 9.6 Hz, *J* = 2.3 Hz), 7.40 (1H, ddd, *J* = 11.2 Hz, *J* = 9.4 Hz, *J* = 2.3 Hz), 7.44–7.47 (2H, m), 7.68–7.70 (2H, m) 7.72 (1H, ddd, *J* = 8.2 Hz, *J* = 7.1 Hz, *J* = 1.3 Hz), 7.80 (1H, ddd, *J* = 8.4 Hz, *J* = 6.9 Hz, *J* = 1.5 Hz), 8.13 (1H, ddd, *J* = 8.4 Hz, *J* = 1.3 Hz, *J* = 0.6 Hz), 8.73 (1H, ddd, *J* = 8.1 Hz, *J* = 1.5 Hz, *J* = 0.6 Hz), 13.27 (1H, s, N*H*). δ_C (100.6 MHz; DMSO; Me_4Si) 21.0 (CH_3), 100.3 (dd, ^2J = 29.9 Hz, ^2J = 20.6 Hz, CH), 102.4 (dd, ^2J = 25.2 Hz, ^4J = 3.9 Hz, CH), 112.1 (C), 116.3 (C), 122.3 (CH), 123.7 (d, ^3J = 13.9 Hz, C), 124.4 (dd, ^3J = 11.4 Hz, ^4J = 6.4 Hz, C), 125.9 (CH), 128.7 (2 × CH), 129.0 (2 × CH), 129.1 (CH), 129.3 (CH), 137.1 (C), 138.6 (C), 142.4 (C), 145.4 (C), 148.3 (dd, ^1J = 246.8 Hz, ^3J = 14.5 Hz, C), 155.5 (C), 155.8 (dd, ^1J = 236.0 Hz, ^3J = 10.1 Hz, C). MS-ESI: *m*/*z*: 345 (M − H^+, 100%).

8,10-Dichloro-6-(4-methylphenyl)-11*H*-indolo[3,2-*c*]quinoline (4l). (0.083 g, 75%). Found C, 70.1; H, 3.7; N, 7.5. Calcd for $C_{22}H_{14}Cl_2N_2$: C, 70.0; H, 3.7; N, 7.4. IR (KBr): ν_{max}/cm^{-1} 3421.03, 1649.25, 1503.92, 757.22. δ_H (400 MHz; DMSO; Me_4Si) 2.50 (3H, s, CH_3), 7.41 (1H, dd, J = 1.9 Hz, J = 0.3 Hz), 7.46–7.48 (2H, m), 7.65–7.66 (1H, m), 7.69–7.71 (2H, m) 7.72 (1H, ddd, J = 8.2 Hz, J = 7.0 Hz, J = 1.3 Hz), 7.81 (1H, ddd, J = 8.4 Hz, J = 6.9 Hz, J = 1.5 Hz), 8.13 (1H, ddd, J = 8.5 Hz, J = 1.1 Hz, J = 0.5 Hz), 8.93 (1H, dd, J = 8.3 Hz, J = 1.3 Hz), 13.07 (1H, s, N*H*). δ_C (100.6 MHz; DMSO; Me_4Si) 21.0 (CH_3), 111.8 (C), 116.3 (C), 117.4 (C), 119.1 (CH), 122.9 (CH), 124.1 (CH), 124.2 (C), 124.3 (C), 125.8 (CH), 128.7 (2 × CH), 129.0 (2 × CH), 129.2 (CH), 129.3 (CH), 137.2 (C), 138.7 (C), 142.2 (C), 142.8 (C), 145.4 (C), 155.5 (C). MS-ESI: *m*/*z*: 381 (M^+ ^{37}Cl – ^{37}Cl + H, 10%), 379 (M^+ ^{37}Cl – ^{35}Cl + H, 60), 377 (M^+ ^{35}Cl – ^{35}Cl + H, 100).

Procedure for the preparation of 6-methyl-11*H*-indolo[3,2-*c*]-quinoline (4m). Catalyst A (0.011 g, 0.014 mmol) was added to a solution of 2,2′-(ethyne-1,2-diyl)dianiline **1a** (0.060 g, 0.29 mmol). The mixture was stirred at r.t. for 8 h. Then, the mixture was evaporated. Column chromatographic purification of the crude on silica gel (hexane–EtOAc 90 : 10) afforded 6-methyl-11*H*-indolo[3,2-*c*]quinoline **4m**: 0.065 g, 96% yield.

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