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Preparation of 2-substituted 8-quinolinols containing C, N, O-donor atoms and its Pd^{II} or Pt^{II} complexes

Akio Yoneda ★

Department of Applied Chemistry, Himeji Institute of Technology, 2167 Shosha, Himeji, Hyogo 671-22 (Japan)

George R. Newkome and Kevin J. Theriot

Department of Chemistry, University of South Florida, Tampa, FL 33620 (U.S.A.)

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Abstract

2-Substituted 8-quinolinols possessing two- (**4**) or three- (**6**) carbon side chains have been prepared from 2-formyl-8-quinolinol. A carbanion, generated on the side chain, serves as the *C*-donor of the bonding triad. The complexation with Pd^{II} or Pt^{II} salts in the presence of pyridine, as an external ligand, afforded the desired neutral chelates having M–C σ-bond as well as the 2:1 ML_2 complex, possessing the intact methine proton. In the case of **6c** possessing a pendant acetylacetonyl moiety, the ^1H NMR spectrum suggested a predominance of the enol form, and upon complexation, the 2:1 ML_2 complex was formed. Since these new ligands have three different hetero donor atoms, a novel palladium complex containing four different (*C, N, O, P*) coordinating sites, by the use of tri(n-butyl)phosphine as an external ligand, was prepared.

Introduction

8-Quinolinol is a classic bidentate ligand, possessing two different binding loci, which forms stable metal chelates that have been shown to exhibit anti-bacterial action [1]. Studies on correlating pharmaceutical activity with chelation by 8-quinolinol and related compounds have recently been reported [2]. Since 2-alkyl/aryl substitution generally results in metal chelates with diminished stability relative to 8-quinolinol, presumably due to steric interactions inhibiting chelate formation [3], pharmaceutical activity has been shown [1,2] to be diminished. 2-Substituted 8-quinolinols, containing an additional side-chain *N*- or *O*-donor site, have been prepared [4], and their complexes have generally fused 5,5- or 5,6-bicyclic chelate-ring systems thus improving stability over the corresponding 8-quinolinol complexes. Since the pendant donor atom was previously limited to either nitrogen or oxygen, the present study expands this series to include carbon which generates ligands possessing three different hetero donor atoms. With an external fourth ligand, the resultant complex would be capable of possessing a novel chiral center with tetrahedral metals.

The ligands were prepared by the reactions outlined in Scheme 1.

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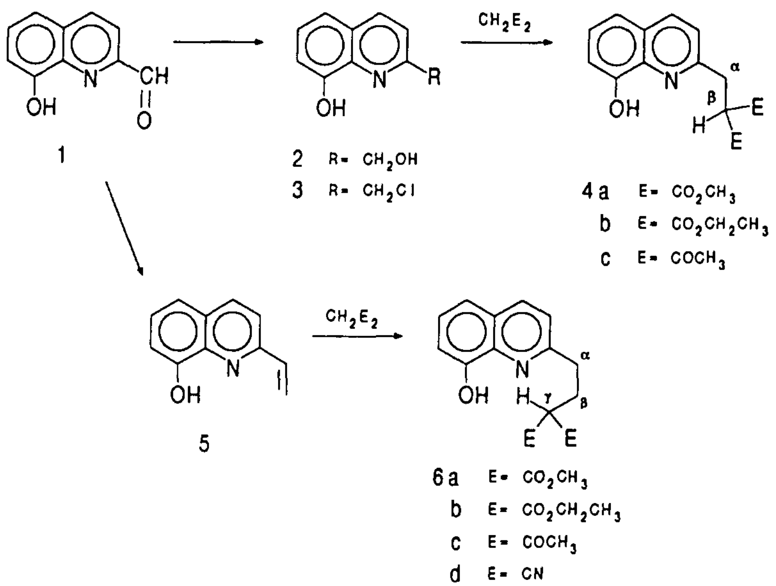


Scheme 1

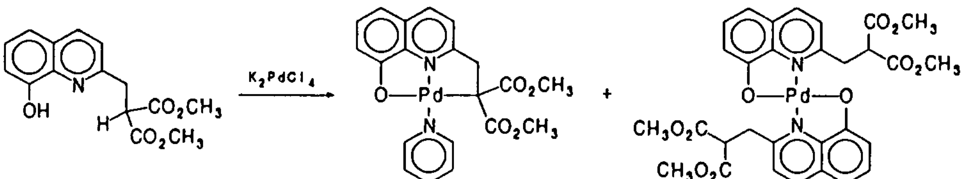
Results and discussion

The available [5] starting aldehyde **1** was readily reduced (92%) with $NaBH_4$ in methanol to give carbinol **2**, which was characterized by the appearance in the ^1H NMR spectrum of a singlet at δ 4.97 for the α-methylene hydrogens. Treatment of **2** with redistilled thionyl chloride at 0 °C afforded (83%) chloromethyl derivative **3**. *Care must be excercised in handling **3**, since it can be extremely irritating to the skin and mucous membranes.* The singlet (^1H NMR) for the α-CH_2 at δ 4.83 and the appearance (IR) of an absorption at 722 cm^{-1} are indicative of the chloromethyl derivative. The substituted malonates **4a, 4b** were prepared by a facile K_2CO_3–DMF procedure [6] in ca. 40% yield, which was not optimized, and spectrally characterized by the doublet at δ 3.67 and triplet at ca. δ 4.29 for the α-CH_2 and β-CH, respectively. These characteristic peaks for α-CH_2 and β-CH for **4** absorbed at significantly lower fields than that of diethyl n-butylmalonate [β-CH(δ 3.17); α-CH_2 (δ 1.89)] [7]; this can be rationalized in terms of an electronic effect due to the electron-withdrawing 8-quinolinol group.

The analogs **6** were prepared by Michael addition of the respective sodio-reagent to 2-vinyl-8-quinolinol [8], which was easily synthesized from the corresponding aldehyde **1** via a Wittig reaction. The structure of desired addition product was confirmed by ^1H NMR data for **6**, in which signals at δ 3.15 ± 0.2 and 3.75 ± 0.2 for the α-methylene and γ-methine protons, respectively, were present in the appropriate ratios.

The interaction of the quinolinol N and the acidic methine H was deduced from the ^1H NMR data, namely that for **4** the characteristic peak of the methine H absorbed at significantly lower magnetic field than **6**. The methine signal intensity of **4c** possessing the acetylacetonyl moiety showed the predominant (> 70%) existence of the keto form, whereas **6c** existed predominantly in the enol configuration. These results illustrate that the magnitude of the NH interaction was greater in the ligands containing a two-, rather than three-, carbon atom side chain.

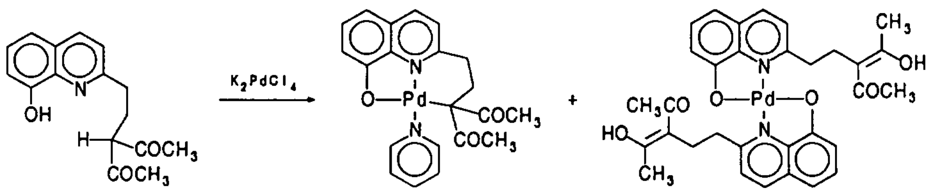
Treatment of **4a** with K_2PdCl_4 in the presence of one quivalent of pyridine afforded two complexes, which were the yellow crystalline Pd(**4a**)py and the 1 : 2 Pd(**4a**)$_2$. The ^{1}H NMR spectra of both complexes showed low field peaks in the δ 6.85 $\pm$ 0.09 range for the quinolinol 5 and/or 7 hydrogen(s) indicating the presence of N,O–Pd bonds. The β-methine H remained a distinct triplet at δ 4.48 ($J = 7.6$ Hz) for Pd(**4a**)$_2$; whereas for Pd(**4a**)py, this signal disappeared and a singlet for the α-CH_2 appeared at δ 4.00 confirming Pd–C bond formation. The externally N-bonded pyridine was also ascertained from the ^{1}H NMR data. The carbonyl absorbance in the IR spectra further supported the Pd–C bond by the 50 cm^{-1} shift for the C=O stretching frequency for Pd(**4a**)py [1713 and 1680 cm^{-1} versus 1751 and 1735 for **4a** and Pd(**4a**)$_2$].



4a | Pd-4a-py | Pd-(4a)$_2$

The ^{1}H NMR spectrum for Pd(**6b**)py was more complicated than initially anticipated, see Fig. 1. The multiplets at ca δ 4.2 for OCH_2CH_3 in ligand **6b** were transformed to two doublet of quartet at δ 3.70 and 3.96 in complex Pd(**6b**)py. Double irradiation indicated the geminal coupling ($J = 11$ Hz) for the ester methylenes; thus, this magnetically nonequivalent environment suggests that the six-membered ring exists in a fixed configuration at 20 °C in chloroform.

When ligand **6c**, possessing the acetylacetonyl moiety, was treated with K_2PdCl_4 in the presence of pyridine, two complexes were isolated and characterized. The ^{1}H NMR spectra confirm the Pd–C bond in Pd(**6c**)py by the loss of the methine-H signal and the presence of signals for pyridine. Since the spectrum for Pd(**6c**)$_2$ did not possess either the pyridine or methine hydrogens, it was concluded that the complex existed exclusively in the enol configuration based on the presence of a singlet at δ 2.17 assigned to $C(OH)CH_3$.



6c | Pd-6c-py | Pd-[6c(enol)]$_2$

The Pt(**6b**)py complex was synthesized (24%) similarly except that mild heating and acetonitrile, was used as solvent. The ^{1}H NMR spectrum for Pt(**6b**)py exhibited shifts similar to the palladium analogue. The differences between Pd/Pt(**6b**)py were less than 0.5 ppm for corresponding signals; for example, the α- and β-methylene

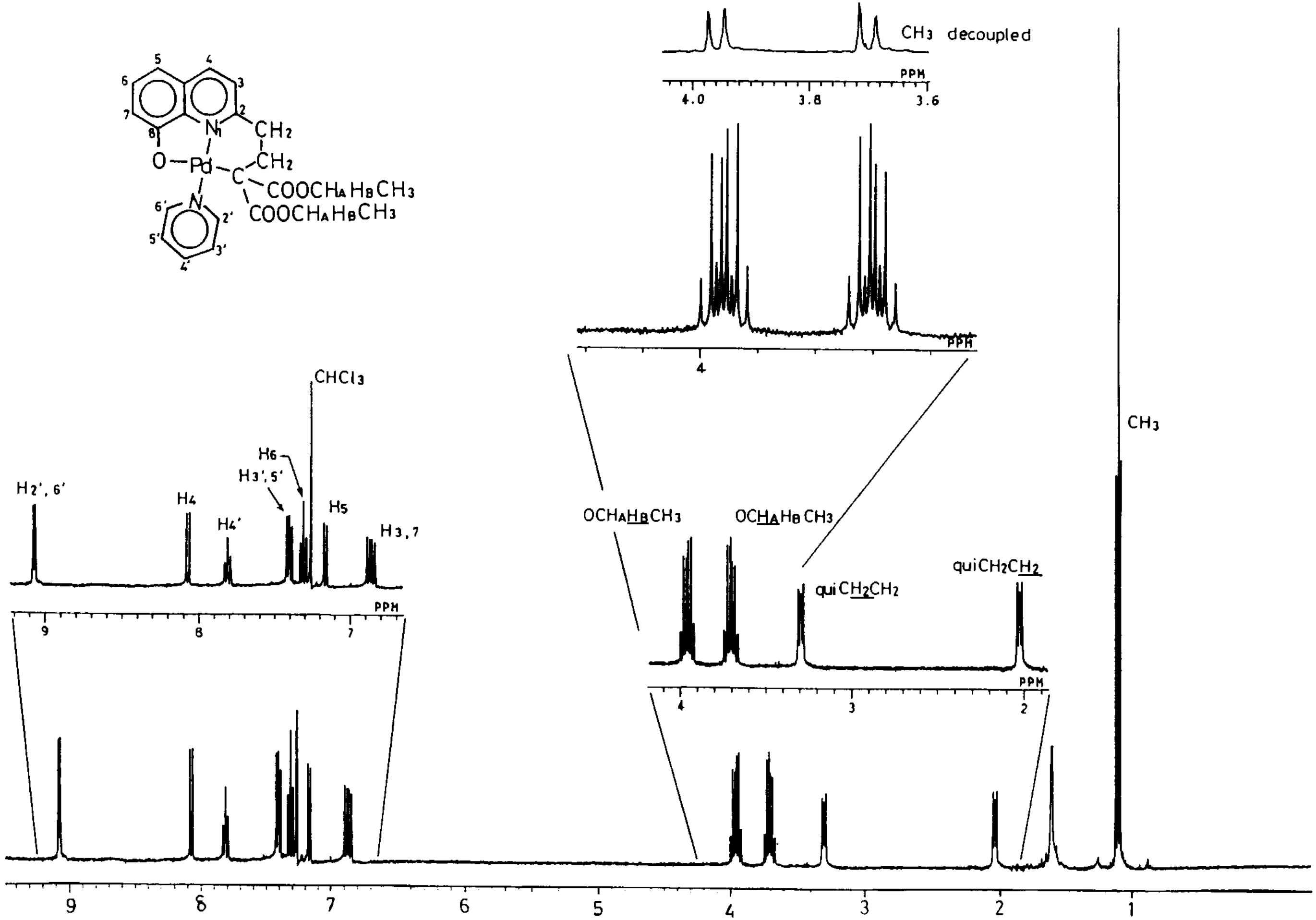


Fig. 1. ^{1}H NMR spectrum of Pd(6b)py in $CDCl_3$.

protons for Pt(**6b**)py were shifted upfield (0.10 ppm) and downfield (0.17 ppm), respectively, in relation to the palladium analogue. The ^{13}C NMR spectrum of Pt(**6b**)py indicated a characteristic small signal at δ 29.4 for Pt*C*. The IR data showed a smaller shift (20 cm^{-1}) for the carbonyl absorption than that for the ligand **6b**.

These 2-substituted 8-quinolinols act as tridentate ligands and form stable *C*-, *N*-, *O*-complexes having fused 5,5- or 5,6-bicyclic chelate-ring with Pd^{II} or Pt^{II} in the presence of external ligands, such as pyridine. The external ligand is readily replaced giving rise to other related complexes. Treatment of Pd(**4a**)py in benzene with tri(n-butyl)phosphine, which readily displaced pyridine, generated (80%) the desired yellow crystalline complex Pd(**4a**)P, which possesses four different donor atoms at palladium. The square planar configuration at the metal core is denoted by the first order ^{1}H NMR spectrum; singlets at δ 3.95 and 3.63 for the α-methylene and carbomethoxy groups, respectively. Studies are currently underway to incorporate a divalent, tetrahedral metal atom to confirm the presence of a chiral core.

Experimental

General comments. Melting points were measured with a Yanaco Micro Melting Point apparatus and are uncorrected. ^{1}H and ^{13}C NMR spectra were determined on a JEOL JNM-GX400 FT NMR spectrometer with $CDCl_3$ as solvent and $CHCl_3$ as the internal standard. IR spectra were recorded on a JASCO FT/IR-5M spectrophotometer. For preparative thick-layer chromatography (TLC), 2 mm silica gel Kieselgel 60 PF254-366 plates were used. Elemental analyses were performed on a Yanaco MT2 CHN recorder.

2-Formyl-8-quinolinol (1) was prepared (91%) by the method of Hata and Uno [5]: mp 98°C (lit. [5] mp 98°C).

2-Hydroxymethyl-8-quinolinol (2) was synthesized by a modified procedure outlined by Chaikin and Brown [9]. To a stirred solution of $NaBH_4$ (400 mg, 10.6 mmol) in CH_3OH (200 mL), was added a solution of 2-formyl-8-quinolinol (3.46 g, 20 mmol) in CH_3OH (100 mL) dropwise during 12 min at 25°C. After stirring for an additional 30 min, the light yellow solution was concentrated in vacuo, and water (200 mL) was added. The mixture was neutralized with 1 *N* HCl, extracted with EtOAc (200 mL), dried over anhydrous Na_2SO_4, and concentrated in vacuo to give the desired product, which was recrystallized from EtOAc–C_6H_{14} (1:4) to give (92%) **2**, as colorless crystals: 3.22 g; mp 122°C; ^{1}H NMR δ 4.97 (s, CH_2, 2H), 7.22 (d, 5-quin*H*, $J = 8.3$ Hz, 1H), 7.35 (d, 7-quin*H*, $J = 8.3$ Hz, 1H), 7.39 (d, 3-quin*H*, $J = 8.3$ Hz, 1H), 7.46 (t, 6-quin*H*, $J = 7.8$ Hz, 1H), 8.16 (d, 4-quin*H*, $J = 8.3$ Hz, 1H); IR 3300, 1598, 1571 (C=C), 1043 (CH_2OH) cm^{-1}. Anal. Calcd for $C_{10}H_9NO_2$: C, 68.56; H, 5.18; N, 8.00. Found: C, 68.47; H, 5.24; N, 7.77%.

2-Chloromethyl-8-quinolinol (3) was prepared by a modified procedure of Baker et al. [10]. To 2-hydroxymethyl-8-quinolinol (3.90 g, 22 mmol), redistilled $SOCl_2$ (30 mL) at 0°C was slowly added. The mixture was stirred for 1 h, then excess $SOCl_2$ was removed in vacuo to give the crude yellow hydrochloride, which was dissolved in CH_2Cl_2 (200 mL), basified slightly with saturated aqueous Na_2CO_3, dried over anhydrous Na_2SO_4, and lastly concentrated in vacuo. The residue was chromatographed (TLC) on silica gel eluting with EtOHc–C_6H_{14} (1:4) to give the desired product, which was recrystallized from C_6H_{14} to give (83%) **3**, as colorless crystals:

3.57 g; mp 56 °C; ^{1}H NMR δ 4.83 (s, CH_2Cl, 2H), 7.20 (d, 5-quin$H$, $J = 7.8$ Hz, 1H), 7.34 (d, 7-quin$H$, $J = 8.3$ Hz, 1H), 7.47 (t, 6-quin$H$, $J = 7.8$ Hz, 1H), 7.62 (d, 3-quin$H$, $J = 8.8$ Hz, 1H), 8.20 (d, 4-quin$H$, $J = 8.8$ Hz, 1H); IR 3420 (OH), 1600, 1570 (C=C), 722 (CH_2Cl) cm^{-1}. Anal. Calcd for $C_{10}H_8NOCl$: C, 62.03; H, 4.16; N, 7.23. Found: C, 62.12; H, 4.08; N, 7.12%.

*2-[2,2-Bis(methoxycarbonyl)ethyl]-8-quinolinol (**4a**).* A mixture of 2-chromethyl-8-quinolinol (658 mg, 3.4 mmol), dimethyl malonate (700 mg, 5.3 mmol), and anhydrous K_2CO_3 (1.62 g, 11.7 mmol) in dry DMF [11] (15 mL) was stirred at 25 °C for 6 h. After 24 h, the mixture was filtered, and the residue was thoroughly washed with CH_2Cl_2. The combined organic extract was concentrated in vacuo to afford a light yellow oil, which was chromatographed (TLC) on silica gel eluting with EtOAc–C_6H_{14} (1 : 4) to give (45%) **4a**, as colorless crystals: 440 mg; mp 90 °C; ^{1}H NMR δ 3.68 (d, α-CH_2, $J = 7.8$ Hz, 2H), 3.79 (s, CH_3, 6H), 4.30 (t, β-CH, $J = 7.8$ Hz, 1H), 7.15 (d, 5-quin$H$, $J = 7.8$ Hz, 1H), 7.30 (d, 7-quin$H$, $J = 8.3$ Hz, 1H), 7.34 (d, 3-quin$H$, $J = 8.8$ Hz, 1H), 7.41 (t, 6-quin$H$, $J = 7.8$ Hz, 1H), 8.07 (d, 4-quin$H$, $J = 8.8$ Hz, 1H); IR 3400 (OH), 1747 (C=O), 1600, 1577 (C=C) cm^{-1}. Anal. Calcd for $C_{15}H_{15}NO_5$: C, 62.28; H, 5.23; N, 4.84. Found: C, 62.20; H, 5.18; N, 4.79%.

*2-[2,2-Bis(ethoxycarbonyl)ethyl]-8-quinolinol (**4b**)* was synthesized (37%) similarly except for the substitution of diethyl malonate: mp 59 °C; ^{1}H NMR δ 1.28 (t, CH_3, $J = 7.1$ Hz, 6H), 3.67 (d, α-CH_2, $J = 7.3$ Hz, 2H), 4.25 (q, OCH_2, $J = 7.1$ Hz, 4H), 4.27 (t, β-CH, $J = 7.6$ Hz, 1H), 7.15 (d, 5-quin$H$, $J = 7.8$ Hz, 1H), 7.29 (d, 7-quin$H$, $J = 8.3$ Hz, 1H), 7.34 (d, 3-quin$H$, $J = 8.3$ Hz, 1H), 7.40 (t, 6-quin$H$, $J = 7.8$ Hz, 1H), 8.07 (d, 4-quin$H$, $J = 8.3$ Hz, 1H); IR 3385 (OH), 1735 (C=O), 1602, 1576 (C=C) cm^{-1}. Anal. Calcd for $C_{17}H_{19}NO_5$: C, 64.34; H, 6.04; N, 4.41. Found: C, 64.36; H, 6.22; N, 4.30%.

*2-[2,2-Bis(acetyl)ethyl]-8-quinolinol (**4c**)* was similarly synthesized (66%) using 2,4-pentanedione. The crude product was chromatographed (TLC) on silica gel eluting with EtOAc–C_6H_{14} (1 : 4) to give **4c**, as a viscous colorless oil: ^{1}H NMR (keto form) δ 2.27 (s, CH_3, 4.2H), 3.57 (d, α-CH_2, $J = 7.3$ Hz, 1.4H), 4.54 (t, β-CH, $J = 7.3$ Hz, 0.7H), 7.17 (d, 5-quin$H$, $J = 7.8$ Hz, 0.7H), 7.29 (d, 7-quin$H$, $J = 8.3$ Hz, 0.7H), 7.34 (d, 3-quin$H$, $J = 8.3$ Hz, 0.7H), 7.41 (t, 6-quin$H$, $J = 7.8$ Hz, 0.7H), 8.07 (d, 4-quin$H$, $J = 8.3$ Hz, 0.7H); (enol form) δ 2.14 (s, CH_3, 0.8H), 2.14 [s, C(OH)CH_3, 0.7H], 3.99 (s, α-CH_2, 0.5H), 7.16 (d, 5-quin$H$, $J = 7.8$ Hz, 0.3H), 7.29 (d, 7-quin$H$, $J = 8.3$ Hz, 0.3H), 7.31 (d, 3-quin$H$, $J = 8.3$ Hz, 0.3H), 7.42 (t, 6-quin$H$, $J = 7.8$ Hz, 0.3H), 8.10 (d, 4-quin$H$, $J = 8.3$ Hz, 0.3H); IR 3420 (OH), 1728, 1700 (C=O), 1600, 1575 (C=C) cm^{-1}. Anal. Calcd for $C_{15}H_{15}NO_3$: C, 70.02; H, 5.88; N, 5.44. Found: C, 70.07; H, 6.10; N, 5.45%.

*2-[3,3-Bis(methoxycarbonyl)propyl]-8-quinolinol (**6a**)* was synthesized by the modified procedure of Shono et al. [12]. To a stirred solution of dimethyl malonate (500 mg, 3.8 mmol), and sodium methoxide (22 mg, 0.4 mmol) in dry methanol (20 mL) was added 2-vinyl-8-quinolinol (100 mg, 0.6 mmol) [8] in methanol (10 mL) under reflux. After 24 h, the solution was concentrated in vacuo to give a crude oil, which was extracted with 2-propyl ether (30 mL). The organic extract was washed with 1 N HCl, then 1 N NaOH, dried over anhydrous Na_2SO_4, and concentrated in vacuo to afford an oil, which was chromatographed (TLC) on silica gel eluting with EtOAc–C_6H_{14} (1 : 4) to give (39%) the desired ligand **6a**, as a colorless oil: 70 mg; ^{1}H NMR δ 2.50 (dt, β-CH_2, $J = 7.3$, 7.3 Hz, 2H), 3.05 (t, α-CH_2, $J = 7.3$ Hz, 2H), 3. 60 (t,

γ-CH, $J = 7.3$ Hz, 1H), 3.75 (s, OCH_3, 6H), 7.16 (d, 5-quin$H$, $J = 7.6$ Hz, 1H), 7.29 (d, 7-quin$H$, $J = 8.1$ Hz, 1H), 7.30 (d, 3-quin$H$, $J = 8.5$ Hz, 1H), 7.40 (t, 6-quin$H$, $J = 7.6$ Hz, 1H), 8.07 (d, 4-quin$H$, $J = 8.5$ Hz, 1H); IR 3400 (OH), 2940, 1733 (C=O), 1600, 1570 (C=C) cm^{-1}. Anal. Calcd for $C_{16}H_{17}NO_5$: C, 63.36; H, 5.65; N, 4.62. Found: C, 63.42; H, 5.88; N, 4.61%.

*2-[3,3-Bis(ethoxycarbonyl)propyl]-8-quinolinol (**6b**)* was synthesized (36%) as above except for the substitution of diethyl malonate: oil; ^{1}H NMR δ 1.27 (t, CH_3, $J = 7.3$ Hz, 6H), 2.48 (dt, β-CH_2, $J = 7.3$, 7.3 Hz, 2H), 3.05 (t, α-CH_2, $J = 7.3$ Hz, 2H), 3.55 (t, γ-CH, $J = 7.3$ Hz, 1H), 4.17–4.24 (m, OCH_2, 4H), 7.15 (d, 5-quin$H$, $J = 7.8$ Hz, 1H), 7.29 (d, 7-quin$H$, $J = 7.8$ Hz, 1H), 7.31 (d, 3-quin$H$, $J = 8.3$ Hz, 1H), 7.40 (t, 6-quin$H$, $J = 7.8$ Hz, 1H), 8.07 (d, 4-quin$H$, $J = 8.3$ Hz, 1H); IR 3400 (OH), 1721 (C=O), 1598, 1568 (C=C) cm^{-1}. Anal. Calcd for $C_{18}H_{21}NO_5$: C, 65.24; H, 6.39; N, 4.23. Found: C, 65.10; H, 6.41; N, 4.00%.

*2-[3,3-Bis(acetyl)propyl]-8-quinolinol (**6c**)* was synthesized (49%) as above using 2,4-pentanedione: oil, ^{1}H NMR δ 2.14 [s, CH_3(enol form), 5.4H], 2.19 [s, CH_3(keto form), 0.6H], 2.51 (t, β-CH_2, $J = 7.3$ Hz, 2H), 2.98 (t, α-CH_2, $J = 7.3$ Hz, 2H), 3.75 [t, γ-CH(keto form), $J = 7.6$ Hz, 0.1H], 7.15 (d, 5-quin$H$, $J = 7.8$ Hz, 1H), 7.29 (d, 7-quin$H$, $J = 7.3$ Hz, 1H), 7.31 (d, 3-quin$H$, $J = 8.3$ Hz, 1H), 7.39 (t, 6-quin$H$, $J = 7.8$ Hz, 1H), 8.06 (d, 4-quin$H$, $J = 8.3$ Hz, 1H); IR 3380 (OH), 1707 (C=O), 1597, 1568 (C=C) cm^{-1}. Anal. Calcd for $C_{16}H_{17}NO_3$: C, 70.83; H, 6.32; N, 5.16. Found: C, 71.11; H, 6.48; N, 5.43%.

*2-(3,3-Dicyanopropyl)-8-quinolinol (**6d**)* was synthesized (41%) as above using malonitrile: oil; ^{1}H NMR δ 2.69 (dt, β-CH_2, $J = 7.2$, 7.3 Hz, 2H), 3.32 (t, α-CH_2, $J = 7.2$ Hz, 2H), 3.91 (t, γ-CH, $J = 7.3$ Hz, 0.9 H), 7.21 (d, 5-quin$H$, $J = 7.8$ Hz, 1H), 7.34 (d, 7-quin$H$, $J = 7.8$ Hz, 1H), 7.37 (d, 3-quin$H$, $J = 8.3$ Hz, 1H), 7.46 (t, 6-quin$H$, $J = 7.8$ Hz, 1H), 8.15 (d, 4-quin$H$, $J = 8.3$ Hz, 1H); IR 3410 (OH), 2260 (C≡N), 1600, 1570 (C=C) cm^{-1}. Anal. Calcd for $C_{14}H_{11}N_3O$: C, 70.87; H, 4.67; N, 17.71. Found: C, 71.01; H, 4.64; N, 17.22%.

*Palladium(II) complex with **4a** and pyridine.* To a stirred solution of ligand **4a** (96 mg, 0.33 mmol) in absolute EtOH (10 mL) was added a solution of K_2PdCl_4 (108 mg, 0.33 mmol) in water (20 mL), followed by the addition of KOH (70 mg, 1.2 mmol). After 20 min at 25°C, pyridine (1 mL) was added and the mixture was stirred for an additional 10 h. The mixture was concentrated in vacuo and the Pd complex was extracted with CH_2Cl_2 and dried over anhydrous Na_2SO_4. Upon concentration, the residue was chromatographed (TLC) on silica gel eluting with EtOAc to give two major components.

Fraction A gave (10%) the 2:1-complex Pd(**4a**)$_2$, as brick-red needles: mp 242–250°C (dec); 11.3 mg; ^{1}H NMR δ 3.69 (s, OCH_3, 12H), 4.00 (d, α-CH_2, $J = 7.6$ Hz, 4H), 4.48 (t, CH, $J = 7.6$ Hz, 2H), 6.76 (d, 5-quin$H$, $J = 7.6$ Hz, 2H), 6.88 (d, 7-quin$H$, $J = 7.8$ Hz, 2H), 7.23 (d, 3-quin$H$, $J = 8.6$ Hz, 2H), 7.30 (t, 6-quin$H$, $J = 7.8$ Hz, 2H), 8.11 (d, 4-Quin$H$, $J = 8.3$ Hz, 2H); IR (KBr) 1751, 1735 (C=O), 1558 (C=C) cm^{-1}. Anal. Calcd for $C_{30}H_{28}N_2O_{10}Pd$: C, 52.76; H, 4.13; N, 4.10. Found: C, 52.82; H, 4.18; N, 4.23%.

Fraction B afforded (34%) the desired complex Pd(**4a**)py, as yellow crystals (CH_2Cl_2–C_6H_{14}): mp 132–134°C (dec); 53.3 mg; ^{1}H NMR δ 3.51 (s, OCH_3, 6H), 4.00 (s, α-CH_2, 2H), 6.88 (d, 5-quin$H$, $J = 8.3$ Hz, 1H), 6.93 (d, 7-quin$H$, $J = 7.3$ Hz, 1H), 7.31 (d, 3-quin$H$, $J = 8.8$ Hz, 1H), 7.35 (t, 6-quin$H$, $J = 7.8$ Hz, 1H), 7.44 (dd, 3- and 5-pyr$H$, $J = 7.8$, 6.3 Hz, 2H), 7.84 (t, 4-pyr$H$, $J = 7.8$ Hz, 1H), 8.12 (d, 4-quin$H$, $J = 8.8$ Hz, 1H), 8.91 (dd, 2- and 6-pyr$H$, $J = 6.3$, 1.5 Hz, 2H); IR (KBr) 1713, 1680 (C=O), 1603, 1568 (C=C) cm^{-1}. Anal. Calcd for $C_{20}H_{18}N_2O_5Pd \cdot 3/2H_2O$: C, 48.06; H, 4.21; N, 5.60. Found C, 47.97; H, 4.00; N, 5.51%.

Palladium(II) complex from ***6b*** *and pyridine* was prepared as described above: Pd(**6b**)py, as yellow crystals ($CHCl_3$–C_6H_{14}); mp 182–184°C; 150 mg (88%); ^{1}H NMR δ 1.10 (t, OCH_2CH_3, $J = 7.3$ Hz, 6H), 2.03 (t, β-CH_2, $J = 5.9$ Hz, 2H), 3.29 (t, α-CH_2, $J = 5.9$ Hz, 2H), 3.70 (dq, $OCH_aH_bCH_3$, $J = 7.1$, 10.9 Hz, 2H), 3.96 (dq, $OCH_aH_bCH_3$, $J = 7.1$, 11.0 Hz, 2H), 6.85 (d, 5-quin$H$, $J = 7.8$ Hz, 1H), 6.88 (d, 7-quin$H$, $J = 7.8$ Hz, 1H), 7.16 (d, 3-quin$H$, $J = 8.8$ Hz, 1H), 7.31 (t, 6-quin$H$, $J = 7.8$ Hz, 1H), 7.40 (dd, 3- and 5-pyr$H$, $J = 7.3$, 6.3 Hz, 2H), 7.81 (t, 4-pyr$H$, $J = 7.3$ Hz, 1H), 8.07 (d, 4-quin$H$, $J = 8.3$ Hz, 1H), 9.08 (dd, 2- and 6-pyr$H$, $J = 6.3$, 1.5 Hz, 2H); IR (KBr) 1700, 1678 (C=O), 1601, 1564 (C=C) cm^{-1}. Anal. Calcd for $C_{23}H_{24}N_2O_5Pd$: C, 53.65; H, 4.70; N, 5.44. Found: C, 53.64; H, 4.83; N, 5.44%.

Palladium(II) complex from ***6c*** *and pyridine* was prepared as above and shown to afford two components. *Fraction A* gave (21%) the 2:1-complex Pd(**6c**)$_2$ (enol form), as brick-red needles ($CHCl_3$–C_6H_{14}): mp 203–209°C (dec); 44 mg; ^{1}H NMR δ 2.17 [s, C(OH)CH_3, 6H], 2.17 (s, $COCH_3$, 6H), 2.72 (t, β-CH_2, $J = 7.3$ Hz, 4H), 3.48 (t, α-CH_2, $J = 7.8$ Hz, 4H), 6.83 (d, 5-quin$H$, $J = 7.8$ Hz, 2H), 6.88 (d, 7-quin$H$, $J = 7.8$ Hz, 2H), 7.26 (d, 3-quin$H$, $J = 8.3$ Hz, 2H), 7.31 (t, 6-quin$H$, $J = 7.8$ Hz, 2H), 8.12 (d, 4-quin$H$, $J = 8.7$ Hz, 2H); IR (KBr) 1710 (C=O); 1560, 1500 (C=C) cm^{-1}. Anal. Calcd for $C_{32}H_{32}N_2O_6Pd$: C, 59.40; H, 4.98; N, 4.33. Found: C, 59.59; H, 5.26; N, 4.29%.

Fraction B afforded (7%) the 1:1-complex Pd(**6c**)py, as yellow crystals ($CHCl_3$–C_6H_{14}): mp 196–199°C: 11 mg; ^{1}H NMR δ 1.70 (s, CH_3, 6H), 3.05 (dd, β-CH_2, $J = 3.9$, 8.3 Hz, 2H), 3.11 (ddd, α-CH_aH_b, $J = 3.4$, 9.3, 17.6 Hz, 1H), 3.82 (dd, α-CH_2H_b, $J = 2.4$, 8.3, 17.6 Hz, 1H), 6.87 (d, 5-quin$H$, $J = 7.8$ Hz, 1H), 6.93 (d, 7-quin$H$, $J = 7.8$ Hz, $J = 7.8$ Hz, 1H), 7.20 (d, 3-quin$H$, $J = 8.3$ Hz, 1H), 7.34 (t, 6-quin$H$, $J = 7.8$ Hz, 1H), 7.45 (dd, 3- and 5-pyr$H$, $J = 7.3$, 6.3 Hz, 2H), 7.84 (dd, 4-pyr$H$, $J = 7.3$, 7.8 Hz, 1H), 8.08 (d, 4-quin$H$, $J = 8.8$ Hz, 1H), 8.87 (d, 2- and 6-pyr$H$, $J = 6.3$ Hz, 2H); IR (KBr) 1640 (C=O), 1602, 1564 (C=C) cm^{-1}. Anal. Calcd for $C_{21}H_{20}N_2O_3Pd \cdot H_2O$: C, 53.34; H, 4.69; N, 5.92. Found: C, 53.52; H, 4.20; N, 6.25%.

Platinum(II) complex from ***6b*** *and pyridine [Pt(****6b****)py].* The preparation of the Pt(II) complex from **6b**, following the above procedure, gave generally poor yields (ca. 6%). Thus, a mixture of **6b** (137 mg, 0.41 mmol), K_2PtCl_4 (172 mg, 0.41 mmol), anhydrous K_2CO_3 (206 mg, 1.5 mmol), $AgNO_3$ (70 mg, 0.41 mmol), and pyridine (1 mL) in anhydrous CH_3CN (30 mL) was stirred at 55 ± 10°C for 20 h. After filtration, the residue was thoroughly washed with CH_2Cl_2. The combined organic extract was concentrated in vacuo to afford a thick yellow oil, which was chromatographed (TLC) eluting with EtOAc. The complex was recrystallized ($CHCl_3$–C_6H_{14}) to give (24%) Pt(**6b**)py pure, as yellow crystals: mp 195–197°C; 59 mg; ^{1}H NMR δ 1.10 (t, OCH_2CH_3, $J = 7.1$ Hz, 6H), 2.20 (t, β-CH_2, $J = 5.9$ Hz, 2H), 3.19 (t, α-CH_2, $J = 5.9$ Hz, 2H), 3.75 (dq, $OCH_aH_bCH_3$, $J = 7.1$, 10.7 Hz, 2H), 3.99 (dq, $OCH_aH_bCH_3$, $J = 7.1$, 11.0 Hz, 2H), 6.84 (d, 5-quin$H$, $J = 7.8$ Hz, 1H), 6.93 (d, 7-quin$H$, $J = 7.8$ Hz, 1H), 7.14 (d, 3-quin$H$, $J = 8.6$ Hz, 1H), 7.33 (t, 6-quin$H$, $J = 7.8$ Hz, 1H), 7.35 (dd, 3- and 5-pyr$H$, $J = 7.3$, 6.8 Hz, 2H), 7.79 (dd, 4-pyr$H$, $J = 7.6$, 7.8 Hz, 1H), 8.11 (d, 4-quin$H$, $J = 8.5$ Hz, 1H), 9.09 (d, 2- and 6-pyr$H$,

$J = 6.3$ Hz, 2H); ^{13}C NMR δ 14.1 (CH$_3$), 29.4 (C–Pt), 30.8 (α-CH$_2$), 37.5 (β-CH$_2$), 59.9 (OCH$_2$), 112.3 (9-quin$C$), 116.2 (7-quin$C$), 121.8 (3-quin$C$), 125.2 (3′,5′-pyr$C$), 128.3 (10-quin$C$), 129.3 (5-quin$C$), 129.4 (6-quin$C$), 137.2 (4-quin$C$), 138.6 (4′-pyr$C$), 154.1 (2′,6′-pyr$C$), 157.6 (8-quin$C$), 167.3 (2-quin$C$), 176.8 (C=O); IR (KBr) 1706, 1687 (C=O), 1605, 1572 (C=C) cm^{-1}. Anal. Calcd for $C_{23}H_{24}N_2O_5Pt$: C, 45.77; H, 4.01; N, 4.64. Found: C, 45.66; H, 3.97; N, 4.54%.

*Palladium(II) complex from **4a** and tri(n-butyl)phosphine*. Pd(**4a**)P was prepared by a modified procedure of Baba et al. [13]. To Pd(**4a**)py (51 mg, 0.1 mmol) dissolved in benzene (10 mL) was added tri(n-butyl)phosphine (36 mg, 0.18 mmol) in benzene (2 mL). The solution was stirred at 25 °C for 12 h and evaporated to dryness in vacuo to afford (84%) Pd(**4a**)P, as yellow crystals: yield 50 mg; mp 81–83 °C, ^{1}H NMR δ 0.95 (t, CH_3, $J = 7.1$ Hz, 9H), 1.50 (m, CH_2CH_2, 12H), 1.84 (m, PCH_2, 6H), 3.63 (s, OCH_3, 6H), 3.95 (s, α-CH_2, 2H), 6.81 (d, 5-quin$H$, $J = 8.0$ Hz, 1H), 6.88 (d, 7-quin$H$, $J = 8.1$ Hz, 1H), 7.32 (m, 3,6-quin$H$, 2H), 8.09 (d, 4-quin$H$, $J = 8.5$ Hz, 1H); ^{13}C NMR δ 13.9 (CH$_3$), 20.1 (CH$_2$CH$_3$), 24.5 (P–CH$_2$$CH_2$), 26.1 (P–$CH_2$), 43.2 ($C$–Pd), 48.2 ($\alpha$-$CH_2$), 51.4 (O$CH_3$), 110.1 (9-quin$C$), 114.8 (7-quin$C$), 117.9 (3-quin$C$), 128.4 (10-quin$C$), 129.9 (6-quin$C$), 137.4 (5-quin$C$), 142.6 (4-quin$C$), 163.0 (8-quin$C$), 170.8 (2-quin$C$), 173.9 ($C$=O); IR (KBr) 2950, 1732, 1701 (C=O), 1570 (C=C), 1500, 1453, 1064, 764, 511 (Pd–C) cm^{-1}. Anal. Calcd for $C_{27}H_{40}NO_5PPd$: C, 54.41; H, 6.76; N, 2.35. Found: C, 54.24; H, 6.41; N, 2.23%.

Conclusion

We have prepared a number of 2-substituted 8-quinolinols possessing side chains with two- and three-, carbon atoms. The terminal active methine group serves as new C-donor site of these 8-quinolinols. The complexation with Pd(II) or Pt(II) formed the stable fused 5,5- or 5,6-bicyclic chelates with a C–M σ-bond in the presence of pyridine. Tri(n-butyl)phosphine readily displaces pyridine and a complex having an asymmetric palladium center surrounded by C, N, O, and P atoms was obtained.

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