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ORIGINAL PAPER

fac-[Re(CO)$_3$L] Complexes Containing Tridentate Monoanionic Ligands (L$^-$) Having a Terminal Amido and Two Amine Ligating Groups

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Abstract Treatment of *fac*-[Re(CO)$_3$(H$_2$O)$_3$]$^+$ with two unsymmetrical tridentate NNN donor ligands (**LH**) based on a diethylenetriamine (dien) moiety with a 2,4,6-trimethylbenzoyl (tmbCO) group linked to a terminal nitrogen of dien through an amide produced the neutral complexes [Re(CO)$_3$(tmbCO-*N,N*-Me$_2$dien)] and [Re(CO)$_3$(tmbCO-dien)]. The [Re(CO)$_3$(tmbCO-*N,N*-Me$_2$dien)] complex crystallized in the space group $P2_1/c$, a = 19.5793 (15), b = 7.4239 (5), c = 14.8071 (10) Å, β = 104.425(5)°, V = 2084.4(3) Å^3, and the [Re(CO)$_3$(tmbCO-dien)] complex crystallized in the space group $C2/c$, a = 36.861 (7), b = 7.3990 (10), c = 14.933 (3) Å, β = 102.145 (8)°, V = 3981.6(12) Å^3. X-ray crystallographic and NMR analyses confirm that in both the solid and solution states the ligands are bound to the *fac*-Re(CO)$_3$ core in a tridentate fashion with the amide group being deprotonated. An important property in radiopharmaceuticals is shape, which in turn depends on ring pucker. For [Re(CO)$_3$(tmbCO-*N,N*-Me$_2$dien)], the two chelate rings have different pucker chirality, as is commonly found for a broad range of metal complexes. However, for *fac*-[Re(CO)$_3$(tmbCO-dien)], the two chelate rings have the same pucker chirality, a finding attributable to two strong intermolecular hydrogen bonds from the NH$_2$ to two waters of crystallization. Impeded by methyl group clashes with chelate ring hydrogens, the tmb ring rotation about the C(amido)–C(tmb) bond is slow on the NMR time scale.

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Introduction

Technetium-99m (^{99m}Tc) is the most widely used diagnostic radionuclide in nuclear medicine [1–4]. The [^{99m}Tc(V)O]$^{3+}$ core has been used most predominantly, but recently the development of the advantageous [^{99m}Tc(CO)$_3$(H$_2$O)$_3$]$^+$ precursor has opened new directions for radiolabeling [5–7]. Schibli et al. showed that agents with the *fac*-^{99m}Tc(I)(CO)$_3^+$ core bearing a tridentate coordinated ligand are more robust and have better pharmacokinetic profiles than agents bearing bidentate ligands [8]. Frequently used chelating ligands contain N, O, or S donor atoms in groups such as carboxyls [9], amines [10, 11], nitrogen heterocycles [12], and thioethers [13, 14]. A neutral metal-containing label is most useful in the development of small (~5 kDa) metal nuclide radiopharmaceuticals for bioconjugation to hormones, small peptides, etc. because such neutral labels are most likely to preserve the biological properties of the tagged species [15]. Complexes made from the non-radioactive *fac*-[Re(CO)$_3$(H$_2$O)$_3$]$^+$ analogue of *fac*-[^{99m}Tc(CO)$_3$(H$_2$O)$_3$]$^+$ generally provide the necessary background to define the chemistry of the ^{99m}Tc agents [13]. A neutral labeling unit can best be achieved by using monoanionic tridentate ligands. The most common negative donor, the carboxyl group, does not allow bioconjugation, however. We recently reported a series of *fac*-[Re(CO)$_3$(NNN)] complexes of monoanionic tridentate ligands with three nitrogen donors (NNN) containing the seldom-used sulfonamido group [16]. In the names of the NNN ligands (**LH**) used here (*cf.* caption of Fig. 1), the **H**'s designate the sulfonamide and amide NH proton that is absent in the facially coordinated deprotonated bound **L**$^-$. The sulfonamido group offers diverse chemistry

and allows bioconjugation through the terminal ligating group. The amido group is very commonly used in bioconjugation chemistry because of its significance in peptides. Although the amido group has been widely used as a ligating group in $M(V)O^{3+}$ radiopharmaceuticals [17], very little use of this group has been made for *fac*-$^{99m}Tc(I)(CO)_3$ agents, especially as a terminal ligating group [18]. Herein, we describe the *fac*-$[Re(CO)_3\mathbf{L}]$ complexes formed by *fac*-$[Re(CO)_3(H_2O)_3]^+$ with tmbCO-*N,N*-Me_2dienH and tmbCO-dienH, containing the monoanionic deprotonated amido ligand bound in a tridentate fashion. Since all compounds described herein have a facial arrangement of the three carbonyls, hereafter the *fac* designation will be used only in referring to general types of compounds and will be omitted when referring to specific compounds.

In *fac*-$[^{99m}Tc(CO)_3\mathbf{L}]$ agents, the bioconjugation emanates from an atom of one chelate ring of the tridentate ligand. Since chelate ring atoms act as a fulcrum, the configuration of asymmetric centers, the shape, and the conformation of the rings can have a large effect on the overall shape of the agent, and hence on its biological activity. Therefore, it is clearly important to understand how the ligand pucker depends on the various components that can influence it (donor atoms, chains linking these atoms, exocyclic substituents, etc.).

Although chelate ring pucker and factors affecting pucker have not been thoroughly examined for radiopharmaceuticals, extensive structural information exists for a large number of complexes with other metals containing chelate rings with an ethylene group bridge between ligating atoms. Many of these structures have been analyzed by using principal component analysis (pca) and other methods [19–26]. When diethylenetriamine-type ligands bind to a metal center in a tridentate fashion, the two five-membered chelate rings can have either δ or λ chirality (Chart 1), leading to four possible combinations of chelate ring chirality: $\delta\lambda$, $\lambda\delta$, $\lambda\lambda$ and $\delta\delta$.

Pca studies on X-ray structures from the Cambridge Structural Database (CSD) of M(dien) structures [19–21] showed that the $\delta\lambda$ and $\lambda\delta$ conformation combinations were found much more frequently than those with the $\lambda\lambda$ and $\delta\delta$ pucker chirality.

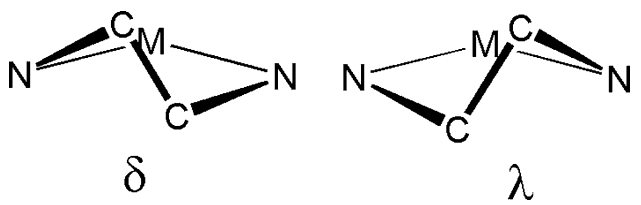

Chart 1 δ and λ chelate ring conformations

Experimental Section

Starting Materials

N,N-dimethyldiethylenetriamine (*N,N*-Me_2dien) from Ames Laboratories, 2,4,6-trimethylbenzoyl chloride (tmbCOCl) from Alfa Aesar, diethylenetramine (dien) and $Re_2(CO)_{10}$ from Aldrich were all used as received. The $[Re(CO)_3(H_2O)_3]OTf$ [13] (OTf = trifluoromethanesulfonate) precursor was prepared by known methods.

NMR Spectroscopy

^1H NMR spectra were recorded on either a 300 MHz or 400 MHz spectrometer. Peak positions are relative to TMS or solvent residual peak, with TMS as reference. All NMR data were processed with XWINNMR and Mestre-C software.

X-ray Data Collection and Structure Determination

All single crystals suitable for X-ray crystallography were obtained by slow evaporation from acetone or methanol.

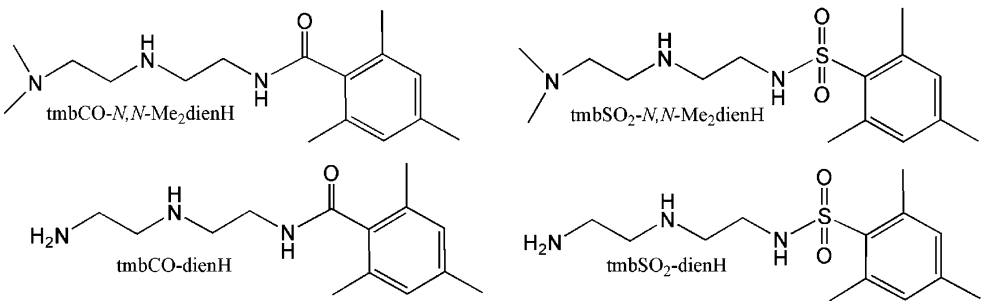

Fig. 1 Ligands used in this study: *N*-[2-(2-dimethylaminoethylamino)-ethyl]-2,4,6-trimethylbenzamide (tmbCO-*N,N*-Me_2dienH); and *N*-[2-(2-aminoethylamino)-ethyl]-2,4,6-trimethylbenzamide (tmbCO-dienH) and ligands referred to in the text: *N*-[2-(2-dimethylaminoethylamino)-ethyl]-2,4,6-trimethylbenzenesulfonamide (tmbSO_2-*N,N*-Me_2dienH) and *N*-[2-(2-aminoethylamino)-ethyl]-2,4,6-trimethylbenzenesulfonamide (tmbSO_2-dienH). The H's in the ligand names designate a sulfonamide/amide proton lost upon Re binding

Single crystals were placed in a cooled nitrogen gas stream at 90 K on a Nonius Kappa CCD diffractometer fitted with an Oxford Cryostream cooler and graphite-monochromated Mo Kα (0.71073 Å) radiation. Data reduction included absorption corrections by the multi-scan method, with HKL SCALEPACK [27]. All X-ray structures were solved by direct methods and difference Fourier techniques and refined by full-matrix least squares techniques using SHELXL97 [28]. All non-hydrogen atoms were refined anisotropically. All hydrogen atoms were visible in difference maps, but were placed in idealized positions with $U_{iso} = 1.2U_{eq}$ for the bonded atom (1.5 for methyl groups). A torsional parameter was refined for each methyl group.

Synthesis of *fac*-[Re(CO)$_3$L]

The crude ligands, **LH**, were synthesized by a slight modification of Krapcho's method [29]. A solution of the acyl chloride (tmbCOCl) (∼5 mmol, 100 mL of dioxane) was added dropwise over the course of about 2 h to a solution of the amine (∼50 mmol, 100 mL of dioxane). The reaction mixture was stirred at RT for 10 h. The dioxane was completely removed under vacuum, and water (50 mL) was added. The product was extracted into CH_2Cl_2 (2 × 100 mL), and the solvent was removed under rotary evaporation. The oil thus obtained was used to synthesize the *fac*-[Re(CO)$_3$**L**] complexes as follows: an aqueous solution of $[Re(CO)_3(H_2O)_3]^+$ (10 mL, 0.1 mmol) was treated with a methanol (5 mL) solution of the ligand (0.1 mmol). The pH was adjusted to ∼5 and the reaction mixture was heated at reflux for 10 h, then allowed to cool at RT, and the pH was increased to ∼7. The resulting white solid that precipitated was collected on a filter, washed with water, and dried under vacuum. This procedure succeeded with **LH** having an amide group, but the procedure was less reliable than for the analogues with the sulfonamide group.

[Re(CO)$_3$(tmbCO-*N,N*-Me$_2$dien)] (**1**)

The general method, with 1 g of tmbCOCl and 6 mL of *N,N*-Me$_2$dien, afforded the crude tmbCO-*N,N*-Me$_2$dienH ligand (650 mg, 45% yield). ^{1}H NMR (ppm) in $CDCl_3$: 6.82 (s, 2H), 6.50 (b, 1H, NH), 3.52 (t, 2H, CH_2), 2.84 (t, 2H, CH_2), 2.68 (t, 2H, CH_2), 2.35 (t, 2H, CH_2), 2.29 (s, 3H, CH_3), 2.26 (s, 6H, CH_3), 2.28 (s, 3H, CH_3), 2.15 (s, 6H, NCH_3). Treatment of $[Re(CO)_3(H_2O)_3]^+$ (0.1 mmol) with tmbCO-*N,N*-Me$_2$dienH (27 mg) as described above afforded [Re(CO)$_3$(tmbCO-*N,N*-Me$_2$dien)] as a white powder, (12 mg, 22% yield). Crystals obtained by slow evaporation from acetone were characterized by single-crystal X-ray crystallography. ^{1}H NMR (ppm) spectrum in acetone-d_6: 6.78 (s, 1H), 6.75 (s, 1H), 6.14 (b, 1H, N2H), 3.47 (m, 1H, CH_2), 3.25 (m, 3H, CH_2), 3.12 (m, 2H, CH_2), 3.12 (s, 3H, NCH_3), 2.97 (s, 3H, NCH_3), 2.87 (m, 2H, CH_2), 2.21 (s, 3H, CH_3), 2.18 (s, 3H, CH_3), 2.13 (s, 3H, CH_3).

[Re(CO)$_3$(tmbCO-dien)] (**2**)

The general method, with tmbCOCl (1 g) and dien (5 mL), yielded the crude tmbCO-dienH ligand (650 mg, 45% yield). ^{1}H NMR (ppm) in $CDCl_3$: 6.80 (s, 2H), 6.27 (b, 1H, NH), 3.53 (t, 2H, CH_2), 2.85 (t, 2H, CH_2), 2.77 (t, 2H, CH_2), 2.67 (t, 2H, CH_2), 2.28 (s, 3H, CH_3), 2.26 (s, 6H, CH_3). Treatment of $[Re(CO)_3(H_2O)_3]^+$ (0.1 mmol) with tmbCO-dienH (25 mg) as described above afforded [Re(CO)$_3$(tmbCO-dien)] as a white powder (15 mg, 29% yield). Crystals obtained by slow evaporation from acetone were characterized by single-crystal X-ray crystallography. ^{1}H NMR (ppm) spectrum in acetone-d_6: 6.79 (s, 1H), 6.75 (s, 1H), 6.16 (b, 1H, N2H), 4.86 (b, 1H, N1H), 4.52 (b, 1H, N1H), 3.31 (m, 1H, CH_2), 3.16 (m, 1H, CH_2), 3.08–2.94 (m, 5H, CH_2), 2.67 (m, 1H, CH_2), 2.20 (s, 3H, CH_3), 2.18 (s, 6H, CH_3).

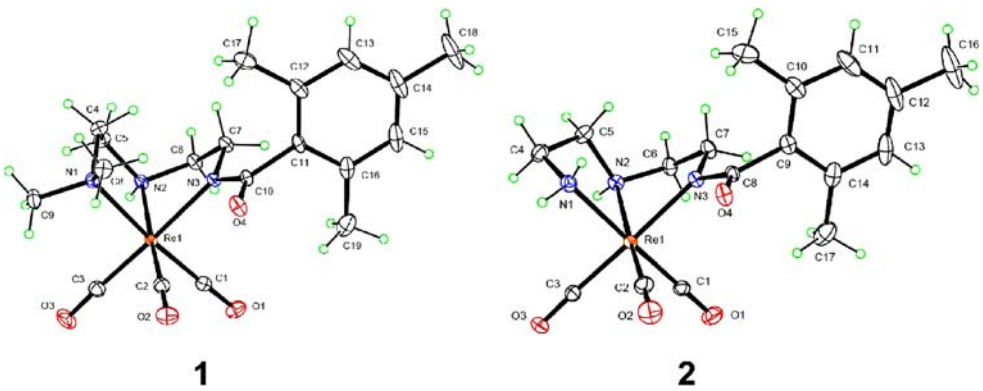

Fig. 2 Perspective drawings of the S configuration of [Re(CO)$_3$(tmbCO-*N,N*-Me$_2$dien)] (**1**) and [Re(CO)$_3$(tmbCO-dien)] (**2**). Thermal ellipsoids are drawn with 50% probability

Results and Discussion

X-Ray Characterization

Both complexes reported here (Fig. 2) have a distorted octahedral structure, with the three carbonyl ligands coordinated facially. The remaining coordination sites are occupied by two sp^3 N amines and one sp^2 N from an amido group. Typically, the Re-C3 bonds, involving the CO group trans to the amido group, are not different from those of the other Re–CO bonds or the respective Re–C3 bonds of the relevant sulfonamido complexes [16]. Crystal data and structural refinement details are summarized in Table 1 for **1** and **2**. Although we found that the aromatic rings facilitated our efforts to obtain crystals, these rings generally were not stacked.

Bond Lengths and Bite Angles

The average Re–N bond length of ~2.2 Å (Table 2) found in the amido complexes is consistent with distances found in relevant *fac*-[Re(CO)$_3$**L**] complexes [11, 14, 16]. The Re–N1 bond (N1Me$_2$ group) in [Re(CO)$_3$(tmbCO-*N,N*-Me$_2$dien)] (**1**) is longer than the other Re-N bonds of **1** and **2**.

Table 1 Crystal data and structural refinement for [Re(CO)$_3$(tmbCO-*N,N*-Me$_2$dien)] (**1**), and [Re(CO)$_3$(tmbCO-dien)] (**2**)

	fac-[Re(CO)$_3$L] complex	
	1	**2**
Empirical formula	$C_{19}H_{26}N_3O_4Re$	$C_{17}H_{22}N_3O_4Re{\bullet}H_2O$
CCDC deposition no.	651285	651286
fw	546.63	536.59
Crystal system	monoclinic	monoclinic
Space group	$P2_1/c$	$C2/c$
Unit cell dimensions		
a (Å)	19.5793 (15)	36.861 (7)
b (Å)	7.4239 (5)	7.3990 (10)
c (Å)	14.8071 (10)	14.933 (3)
β (°)	104.425 (5)	102.145 (8)
V (Å^3)	2084.4 (3)	3981.6 (12)
T (K)	90.0(5)	90.0(5)
Z	4	8
ρ_{calc} (g/cm^3)	1.742	1.790
μ (mm^{-1})	5.857	6.135
Transm. coeff.	0.387–0.474	0.373–0.837
$2\theta_{max}$ (°)	73.8	65.2
R indices[a]	0.027	0.032
wR2 = $[I > 2\sigma(I)]$[b]	0.060	0.077
Data/param	9895/253	7003/245
Resid. dens. (Å^{-3})	1.39, −2.14	1.78, −1.88

Table 2 Selected bond and atom distances (Å) and angles (deg) for [Re(CO)$_3$(tmbCO-*N,N*-Me$_2$dien)] (**1**), and [Re(CO)$_3$(tmbCO-dien)] (**2**)

	fac-[Re(CO)$_3$**L**] complex	
	1	**2**
Bond distances		
Re–N1	2.2738 (19)	2.216 (3)
Re–N2	2.2087 (19)	2.207 (3)
Re–N3	2.1744 (17)	2.185 (3)
Bond angles		
N1–Re–N2	79.37 (7)	77.87 (10)
N2–Re–N3	76.10 (7)	74.26 (10)
N1–Re–N3	85.81 (7)	90.16 (10)
N2–Re–C2	172.33 (9)	170.10 (13)
Non-bonded distances		
N1 to N2	2.863 (2)	2.780 (4)
N2 to N3	2.702 (2)	2.651 (4)
C4 to C7	3.308 (3)	4.169 (4)
C4H to C7H	2.30	4.62
C5 to C6	2.510 (3)	2.468 (4)
C5H to C6H	2.28	2.59

This lengthening is attributed to the bulkiness of the two methyl groups on N1 (for **1**) compared to the smaller H group in **2**. Similar results were observed for the respective bonds of *fac*-[Re(CO)$_3$**L**] (**L** = tmb-sulfonamido ligands) complexes. It is known that the sp^2 N donors can form shorter Re–N bonds than the sp^3 N donors [12, 30]. The Re–N3 sp^2 bond of the amido group in both **1** and **2** is statistically shorter than the respective Re–N1 and Re–N2 bonds (which are Re–sp^3N bonds). The shorter Re–N3 sp^2 bond compared to the Re–N sp^3 bonds was also observed in similar *fac*-[Re(CO)$_3$**L**] (**L** = tmb-sulfonamido ligands) complexes [16]. The effect of the hybridized sp^2 N3 should also be seen in the N3–C7 bond. Indeed, the N3–C7 bond is numerically (but not significantly) shorter than the other sp^3 N–C bonds (N1–C4, N2–C5, and N2–C6). Typical Re–sp^2 N bond lengths range from 2.14 to 2.18 Å, as measured in a several Re structures containing Re–N bonds (aromatic sp^2 N, e.g., in pyridyl ligands), whereas a typical Re–sp^3 N bond length is ~2.2 Å [12–14]. The sp^2 hybridized N3 should affect the C–N3–C7, C–N3–Re, and C7–N3–Re angles. However, the differences between molecules, while generally consistent with expectations for Re–sp^2 N vs. Re–sp^3 N centers, are small and thus are masked by steric and solid state effects. The N–Re–N bite angles in the amido complexes are between 74.2 and 79.3°. The N2–Re–N3 bite angle (ring containing the amido group) is smaller (~75°) than the N1–Re–N2 bite angle (~78°), as found for the related angles in *fac*-[Re(CO)$_3$**L**] (**L** = tmb-sulfonamido ligands) complexes [16]. The N1 to

N2 and N2 to N3 non-bonded distances within five-membered chelate rings in **1** and **2** have a narrow range of values (Table 2) and are similar to those of relevant *fac*-[$Re(CO)_3$**L**] complexes [16], as well as those of complexes with higher valent metal centers [31].

Chelate Ring Chirality

As mentioned in the Introduction, chelate ring shape and conformation affect the overall shape of the bioconjugated agent. In accordance with other relevant compounds [20, 21], and our findings for *fac*-[$Re(CO)_3$**L**] sulfonamido complexes [16], **1** has different chirality in each ring pucker; $\lambda\delta$ for the S configuration at Re (The Re configuration is S for structures shown in Fig. 2) [16]. In contrast, both chelate rings have the same chirality in complex **2** (both δ for the S configuration), a finding we attribute to two strong intermolecular hydrogen bonds from the NH_2 to two waters of crystallization (N···O 2.924(4) at x,y,z and 2.941(4) Å at 1−x, 1−y, 1−z). The fact that complex **2** has the same chirality in both rings is an unusual but not unprecedented finding [16, 19–21]. The non-bonded distances between the chelate rings agree with our previous study [16] finding that C5 to C6 (Table 2) and C5H to C6H distances are not very different whether the pucker chirality of the two chelate rings is the same or different, whereas the C4 to C7 and C4H to C7H distances (*cf*. Fig. 2 for the atom numbering) are larger than when the chirality is different.

We compared the position of the pendant group and the shape and chirality of the ring pucker of complex **1** with its relevant sulfonamido complex [16]. An overlay of the structure of complex **1** and the [$Re(CO)_3$(tmbSO_2-*N,N*-Me_2dien)] complex (Fig. 3) illustrates that even though the dien backbone of the ligand has a very good fit, the location of the pendant tmb group is significantly different. These comparisons indicate that the change from an amido to a sulfonamido ligating group does not affect the backbone structure, but the change in the nature of the linkage of the tmb group to the coordinated nitrogen influences the position of the pendant group.

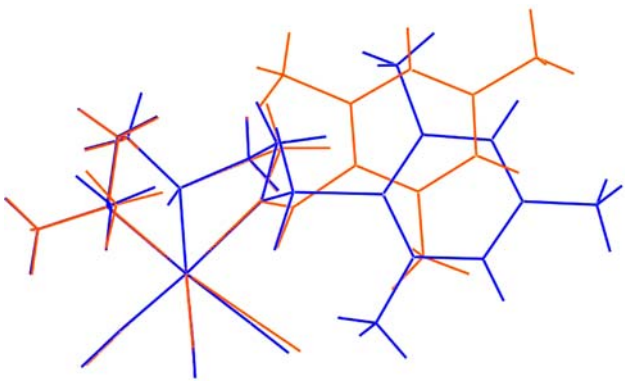

Fig. 3 Overlay of the [$Re(CO)_3$(tmbCO-*N,N*-Me_2dien)] (red) and [$Re(CO)_3$(tmbSO_2-*N,N*-Me_2dien)] (blue) complexes (RMS = 0.026 Å from overlaying the Re, N1, N2, and N3 atoms)

Trimethylbenzyl Group Rotation

In the X-ray structures of **1** and **2** (Fig. 2), the 3 and 5 protons and the 2 and 6 methyl groups of the tmbSO_2 group are not equivalent. Indeed, in the ^{1}H NMR spectra of complexes **1** and **2**, the signals of the magnetically inequivalent two aromatic protons and two methyl groups of the tmbCO group have similar shifts (see "Experimental" Section) but are fully resolved. The signals do not merge when the spectrum in acetone-d_6 is recorded at 40 °C. In contrast, for *fac*-[$Re(CO)_3$**L**] complexes with a sulfonamido group instead of an amido group, these signals are combined for the aromatic and for the methyl protons, indicating fast rotation on the NMR time scale [16].

In the X-ray structures of **1** and **2**, the amido N3–C–O group is planar. Therefore, it can adopt only two orientations with the oxygen facing away or towards the coordination face; in both orientations serious clashes are observed when the tmb group is rotated around the C–C(tmb) bond (with the help of modeling software). The conformer with the oxygen facing towards the coordination face seems to be unfavorable because the tmb group is placed very close to the carbonyl group and rotation of the tmb group would overlap with the carbonyl group. In the second conformer (which is observed in the X-ray structures of **1** and **2**) clashes of the methyl group (of tmb) with the ethylene chain of dien appear to hinder rotation around the C(amido)–C(tmb) bond. Similar clashes were observed also in the relevant *fac*-[$Re(CO)_3$**L**] (**L** = tmb-sulfonamido complexes) complexes [16] during rotation around the C(sulfonamido)–C(tmb) bond. The sulfonamido group S atom is part of longer bonds (N–S and S–C) and a more acute N3–S–C angle compared to the respective bonds (N3–C ~1.32 Å and C–C ~1.51 Å) and angle (N3–C–C ~120°) of the amido group in the [$Re(CO)_3$(tmbCO-dien)] and [$Re(CO)_3$(*N,N*-Me_2tmbCO-dien)] complexes. The equivalence of the tmb signals of the sulfonamido complexes despite the inequivalence in the X-ray structure [16] was attributed to the relatively faster rotation of the tmb group about the S(sulfonamido)–C(tmb) bond of the sulfonamido group compared to the C(amido)–C(tmb) bond of the amido group [32], and that synchronous rotations about the longer N–S and S–C bonds can explain the relatively free rotation of the tmb group for sulfonamido complexes [16]. We believe that for the *fac*-[$Re(CO)_3$**L**] amido complexes (**1** and **2**) the combination of the presence of only

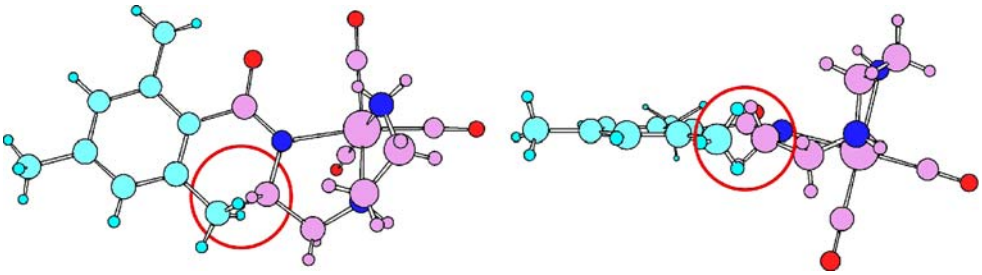

Fig. 4 Two views illustrating the possible steric clashes leading to restricted rotation around the C(amido)–C(tmb) bond for **2**

one favorable conformer, the short bonds and slow rotation of the amido group result in hindered rotation around the C(amido)–C(tmb) bond, from clashes of the methyl group (of tmb) with the ethylene chain (Fig. 4).

NMR Characterization of $[Re(CO)_3L]$ (L^- = tmbCO-*N,N*-Me_2dien$^-$ and tmbCO-dien$^-$)

The *fac*-$[Re(CO)_3\mathbf{L}]$ complexes were characterized by NMR spectroscopy in DMSO-d_6, as well as in acetone-d_6 (Table 3). The $[Re(CO)_3$(tmbCO-dien)] (**2**) complex has a terminal NH_2 group with one NH exo and one NH endo to the tricarbonyl face, which give rise to a relatively upfield *exo*-NH signal (3.94 ppm) and a relatively downfield *endo*-NH signal (4.99 ppm) in DMSO-d_6. These shifts (Table 3) are roughly comparable to those for the terminal NH_2 group of relevant *fac*-$[Re(CO)_3\mathbf{L}]$ ($\mathbf{L}^-$ = tmb-sulfonamido ligands) complexes (3.30–3.54 ppm for upfield NH signal and 5.21–5.26 ppm for downfield NH signal) [16]. The *exo*-NH signal of $[Re(CO)_3$(tmbSO_2-dien)] is ~0.5 ppm more upfield compared to that of **2**, a difference that might be attributed to the different distance of the *exo*-NH protons to the nearest oxygens of the sulfonamido/amido group. The distance of the *exo*-NH of **2** to the oxygen of the CO group is 3.5 Å, whereas the respective distance for the $[Re(CO)_3$(tmbSO_2-dien)] complex is 2.8 Å. The explanation for the relatively upfield shift of the *exo*-NH signal is unclear, but such a signal appears to be a general finding for *fac*-$[Re(CO)_3\mathbf{L}]$ complexes with an *exo*-NH group. One possibility is that steric effects obstruct formation of H-bonds with the solvent, and therefore the downfield shift effect of NH H-bonding to solvent is decreased.

Table 3 Selected chemical shifts (ppm) of $[Re(CO)_3$(tmbCO-*N,N*-Me_2dien)] (**1**), and $[Re(CO)_3$(tmbCO-dien)] (**2**)

	1	**2**
DMSO-d_6		
exo-N1H/Me	2.79	3.94
endo-N1H/Me	3.02	4.99
N2H	6.72	6.69
acetone-d_6		
exo-N1H/Me	2.97	4.53
endo-N1H/Me	3.12	4.86
N2H	6.14	6.17

Conclusions

In our studies we find that the *fac*-$[Re(CO)_3\mathbf{L}]$ amido complexes are much more difficult to synthesize, compared to the related sulfonamido complexes, consistent with the scarcity of related amido complexes in the literature. An inner coordination sphere with a neutral charge is achieved upon binding of the tridentate monoanionic amido ligands in the *fac*-$[Re(CO)_3$(NNN)] complexes studied here. The dangling tmb group connected through the amido bond experiences hindered rotation on the NMR time scale, due to the rigidity of the amido group (compared to the more flexible sulfonamido group). Complex **1** has different chirality in each chelate ring, as commonly found in the literature, whereas complex **2** has the same chirality in each chelate ring. The pendant tmb group has very different positions in $[Re(CO)_3$(tmbCO-*N,N*-Me_2dien)] and $[Re(CO)_3$(tmbSO_2-*N,N*-Me_2dien)]. Therefore, the different linker components (CO and SO_2) lead to different overall shapes.

Supplementary Data

CCDC 651285 and CCDC 651286 contain the supplementary crystallographic data for this paper. These data can be obtained free of charge via www.ccdc.cam.ac.uk/data_request/cif, by e-mailing data_request@ccdc.cam.ac.uk, or by contacting The Cambridge Crystallographic Data Centre, 12 Union Road, Cambridge CB2 1EZ, UK; fax: +44(0)1223-336033.

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