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Preparation of a methyl 3,4-dideoxy-3-*C*-nitro-α-D-*threo*-hex-3-enopyranoside bearing a peroxy function at C-2 and its reactions with some nucleophiles

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Abstract

Treatment of 4,6-diacetate **3** with *tert*-butyl hydroperoxide gave the S_N2' product **6** in high yield, the formation of which presumeably involves an intermediary nitronate. The thus prepared **6** reacted with nucleophiles to afford 2,3-anhydro derivatives having the *talo* configuration.

Keywords: Methyl 3,4-dideoxy-3-*C*-nitro-α-D-*threo*-hex-3-enopyranoside; Peroxy function; S_N2' mechanism

1. Introduction

The S_N2' reaction of α-nitroalkenes having a leaving group at the β′-position is well known and two reaction routes are proposed for this reaction: a concerted one-step mechanism and a stepwise one involving a nitronate [1].

In general the reaction of an α-nitroalkene with peroxide gives the nitroepoxide because of facile cleavage of the O–O bond [2,3]. However, if a suitable leaving group introduced at the β′-position of an α-nitroalkene and a suitable peroxide or peroxy acid are used as a nucleophile, it should be possible to control reactions in which either the nitroepoxide or the S_N2' product becomes the major product. If this is achieved, not only could the unprecedented α-nitroalkene bearing a peroxy group at the β′-position be

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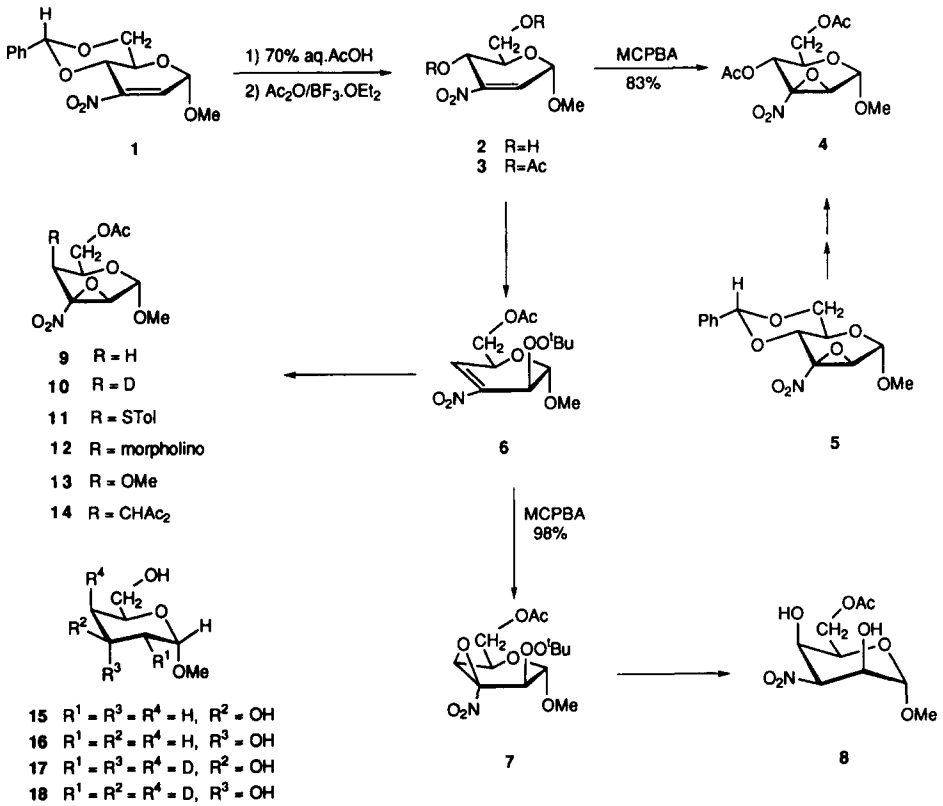
prepared, but also some information about the mechanism of the S_N2' reaction might be obtained. This is indeed realized as described herein [1].

2. Results and discussion

Debenzylidenation of methyl 4,6-*O*-benzylidene-2,3-dideoxy-3-*C*-nitro-α-D-*erythro*-hex-2-enopyranoside (**1**) was performed with hot aqueous acetic acid to give the 4,6-diol **2**. Although acetylation of **2** under basic conditions gave a complicated mixture, treatment with acetic anhydride in the presence of a catalytic amount of boron trifluoride etherate [5] gave the intended 4,6-diacetate **3** in almost quantitative yield. The pure acetate **3** for elemental analysis was obtained by the use of **2** purified by short-column chromatography. The acetate **3** could not withstand chromatographic purification on silica gel, but could be stored in a freezer (−15°C) for at least six months.



Reaction of **3** with *m*-chloroperoxybenzoic acid (MCPBA) in the presence of 1.1 equimolar amount of M NaOH afforded the nitroepoxide **4** in 83% yield. The *manno*

[1] Preliminary results of this work have been published [4].

configuration of **4** is suggested by $J_{1,2}$ value (0 Hz) [2,6] and confirmed by comparison with an authentic sample prepared by debenzylidenation and subsequent acetylation of 2,3-anhydro-4,6-*O*-benzylidene-α-D-mannopyranoside **5** [2,6]. On the other hand, when **3** was similarly treated with *tert*-butyl hydroperoxide, the desired 2-*O*-*tert*-butoxy-3-enopyranoside **6** was obtained in 91% yield, after purification by short-column chromatography. The $^{0}H_{1}$ conformation for **6**, deduced by the small $J_{1,2}$ value (1.0 Hz), should be more stable than the alternative $^{1}H_{0}$ conformation, because of the anomeric effect [7] and $A^{(1,2)}$ strain [8] between the nitro and peroxy groups. A similar conformational preference based on these effects has been reported for methyl 2-*O*-acetyl-3,4,6-trideoxy-3-*C*-nitro-α-L-*threo*-hex-3-enopyranoside [9]. The peroxide **6** thus prepared was unexpectedly stable and could be kept for at least one week at 20°C.

Thus the reaction of **1** with MCPBA afforded the epoxide **4**, whereas that with *tert*-butyl hydroperoxide gave the S_N2' product **6**. In both reactions anionic nucleophiles appear to attack the nitroalkene moiety, because the reactions did not proceed without the base. As formation of the epoxide **4** involves an intermediate nitronate, it is reasonable to assume that the S_N2' product **6** also formed via a nitronate. Such a difference in behavior between the peroxy acid and peroxide may be attributed to the different potential for subsequent bond cleavage. If this is so, the facility for the bond cleavage should decrease according to the sequence; O–O(CO)(*m*)C_6H_4Cl > C–OAc > O–OBu^t. If this sequence is correct and the reaction occurs via a nitronate, reaction of **6** with MCPBA should give the 3,4-anhydro-2-*O*-*tert*-butoxy derivative **7** rather than the 2,3-anhydro-4-*O*-acyloxy derivative. In fact, oxidation of **6** with MCPBA afforded **7** in 98% yield. The H-2 signal (δ 5.42 in $CDCl_3$) of **7** appeared exceptionally at lower field than the H-1 signal (δ 4.73), probably because of anisotropy of the nitro group. This was confirmed by $^{1}H-^{13}C$ COSY and NOE difference spectra irradiated at the OMe signal. In order to determine the configuration of **7**, we performed hydrogenolytic opening of the oxirane ring, because Baer and co-workers [10] have shown for 2,3-anhydro-3-*C*-nitro derivatives that ring opening occurred regiospecifically between oxygen and the carbon atom bearing the nitro group. Hydrogenolysis of **7** with palladium on activated carbon afforded the 3-*C*-nitro-talopyranoside **8** in 59% yield, indicating the *talo* configuration for **7**.

Although introduction of nucleophiles at the C-2 position of 3-nitro sugars has been carried out extensively [11], few similar reactions at C-4 have been described [12]. Since the peroxide **6** has the potential utility for introducing nucleophiles at C-4, it was subjected to reaction with various nucleophiles, to determine whether the reactions afford either a 2,3-anhydro derivative or a 2-enopyranoside (simple S_N2' product). Treatment of **6** with sodium borohydride gave the 2,3-anhydro-4-deoxy derivative **9** in 97% yield. Attack by the nucleophile from the upper side was established by the use of sodium borodeuteride. On exposure to *p*-toluenethiol, compound **6** smoothly gave the 2,3-anhydro-4-mercapto derivative **11** in 95% yield. Morpholine similarly led to the 4-morpholino derivative **12** in 82% yield. Treatment with methanol in the presence of a catalytic amount of lithium methoxide gave the 2,3-anhydro-4-*O*-methyl derivative **13** in 42% yield. 2,4-Pentanedione also reacted with **6** to give the 2,3-anhydro-4-*C*-diacetylmethyl derivative **14** in 46% yield. The *talo* configuration of these products was determined on the basis of the $J_{1,2}$ (~ 0 Hz) and $J_{4,5}$ values (2.6–5.0 Hz), and

confirmed chemically in the case of **10** by reductive denitration with lithium aluminum deuteride. S_N2-Cleavage of the oxirane ring gave the 3-ulose, which then reduced to the alcohols **17** and **18** [6,13]. The equatorial and axial positions at C-2 and C-4 were deuterated in these 3-epimeric products **17** and **18**.

Consequently, all nucleophiles investigated attacked from the axial side of **6**. Axial attack is favored because it generates a chair-like intermediate, whereas the alternative mode of attack would lead to a boat-like intermediate owing to stereoelectronic control [14]. However, axial attack is retarded because of steric hindrance by the acetoxymethyl group at C-5 as well as by the peroxy group at C-2. Such high stereoselectivity indicates that $A^{(1,3)}$ strain [8], which is generated at a nitronate and favors axial attack in the present case, should operate in these reactions.

In conclusion, we have succeeded in preparing an unprecedented pyranosidic nitroalkene having a peroxy group, which is shown to be a useful intermediate for the introduction of nucleophiles at C-4. Furthermore, all nucleophilic addition-reactions to the α-nitroalkenes investigated here appear to proceed via a nitronate, including the S_N2' reaction of **3**.

3. Experimental

General methods.—Melting points are uncorrected. Optical rotations were determined with a Horiba High-sensitivity Polarimeter (SEPA-200). ^1H and ^{13}C NMR spectra were recorded at 270 and 67.8 MHz, respectively, with a JNM-EX270 spectrometer in $CDCl_3$ with Me_4Si as the internal standard. The integration values in the NOE difference spectra are roughly estimated, because measurement conditions were not completely optimized. IR spectra were recorded for KBr pellets. Column chromatography was conducted on silica gel (Wakogel C-300).

*Methyl 2,3-dideoxy-3-C-nitro-α-*D-erythro-*hex-2-enopyranoside* (**2**).—A dispersion of **1** [15] (10 g, 34.1 mmol) in 90% AcOH (100 mL) was heated at 60°C. After stirring for 3 h at 60°C, the mixture was evaporated and azeotropically evaporated with toluene (twice). The yellow solid residue was chromatographed on a short column eluting with 30:1 $CHCl_3$–MeOH to give **2** as a white solid (6.69 g, 96%), which was subjected to elemental analysis without further purification; mp 87–88°C; $[\alpha]_D^{25}$ −91° (*c* 1.0, MeOH); ν_{max} 3440, 3340 (OH), and 1540 cm^{-1} (NO_2); ^1H NMR: δ 5.21 (d, 1 H, $J_{1,2}$ 3.5, $J_{1,4} \leq 1.0$ Hz, H-1), 7.08 (dd, 1 H, $J_{2,4}$ 1.0 Hz, H-2), 4.86 (ddt, 1 H, $J_{4,5}$ 8.6 Hz, H-4), 4.05–3.87 (m, 3 H, H-5,6,6'), 3.51 (s, 3 H, OMe), 3.16 (d, 1 H, $J_{4,OH}$ 3.8 Hz, 4-OH), and 1.94 (dd, 1 H, $J_{6,OH}$ 5.0, $J_{6',OH}$ 7.3 Hz, 6-OH). Anal. Calcd for $C_7H_{11}NO_6$: C, 40.98; H, 5.40; N, 6.83. Found: C, 40.92; H, 5.43; N, 6.73.

*Methyl 4,6-di-*O*-acetyl-2,3-dideoxy-3-C-nitro-α-*D-erythro-*hex-2-enopyranoside* (**3**). —A solution of **2** (4 g, 19.5 mmol) in Ac_2O (40 mL) was cooled to −20°C and a catalytic amount of $BF_3 \cdot Et_2O$ was added. After 6 min, MeOH (50 mL) was slowly added and the mixture was stirred for 30 min at −20°C and evaporated. The residue was azeotropically evaporated with toluene, diluted with EtOAc, washed with aq satd NaCl (twice), dried, and evaporated to give **3** as light yellow crystals (5.53 g, 98%); mp

69–70°C; $[\alpha]_D^{25}$ −29° (*c* 1.1, CH_2Cl_2); ν_{max} 1760 and 1730 (OAc), 1530 cm^{-1} (NO_2); ^1H NMR: δ 5.25 (br d, 1 H, $J_{1,2}$ 3.6 Hz, H-1), 7.16 (dd, 1 H, $J_{2,4}$ 1.3 Hz, H-2), 6.12 (dt, 1 H, $J_{1,4}$ 1.3, $J_{4,5}$ 8.6 Hz, H-4), 4.16 (br td, 1 H, $J_{5,6}$ 3.6, $J_{5,6'}$ 4.3 Hz, H-5), 4.27 (dd, 1 H, $J_{6,6'}$ 12.5 Hz, H-6), 4.20 (dd, 1 H, H-6′), 3.52 (s, 3 H, OMe), 2.13 (s, 3 H, OAc), and 2.08 (s, 3 H, OAc). Anal. Calcd for $C_{11}H_{15}NO_8$: C, 45.68; H, 5.23; N, 4.84. Found: C, 45.57; H, 4.97; N, 4.83.

Methyl 2,3-anhydro-4,6-di-O-*acetyl-3*-C-*nitro-α*-D-*mannopyranoside* (**4**).—(*a*) To a solution of **3** (50 mg, 0.17 mmol) in 1,4-dioxane (2 mL) was added MCPBA(purity 70%, 100 mg, 0.41 mmol) and then M NaOH (0.2 mL). After stirring for 3 min, the mixture was partitioned between M aq HCl and CH_2Cl_2. The organic layer was washed with aq $Na_2S_2O_3$, satd aq NaCl (twice), dried, and evaporated. The resulting residue was chromatographed with 100:1 toluene–EtOAc to give 44 mg (83%) of **4** as a syrup; $[\alpha]_D^{25}$ +67° (*c* 1.1, $CHCl_3$); ν_{max} 1750 (OAc), and 1560 cm^{-1} (NO_2); ^1H NMR: δ 4.97 (s, 1 H, H-1), 3.89 (br s, 1 H, $J_{2,4}$ 1.0 Hz, H-2), 5.51 (dd, 1 H, $J_{4,5}$ 8.9 Hz, H-4), 4.04 (ddd, 1 H, $J_{5,6}$ 4.6, $J_{5,6'}$ 3.3 Hz, H-5), 4.16 (dd, 1 H, $J_{6,6'}$ 12.2 Hz, H-6), 4.21 (dd, 1 H, H-6′), 3.54 (s, 3 H, OMe), and 2.10 (s, 6 H, Ac x 2). Anal. Calcd for $C_{11}H_{15}NO_9$: C, 43.28; H, 4.95; N, 4.59. Found: C, 43.37; H, 4.69; N, 4.63.

(*b*) A solution of **5** [2,6] (10 mg, 0.03 mmol) in aq 90% AcOH (3 mL) was heated at 40°C for 2 days. After evaporation of the AcOH, the residue was evaporated with toluene and chromatographed with 30:1 $CHCl_3$–MeOH to give 7 mg (98%) of debenzylidenated product, which was pure as judged from its ^1H NMR spectrum. The crude product (20 mg, 0.09 mmol) was dissolved in CH_2Cl_2 (2 mL) and cooled to −10°C. To the solution was added pyridine (36 mg, 0.46 mmol) and Ac_2O 55 mg (0.5 mmol). After 18 h at −10°C, the mixture was extracted with CH_2Cl_2. The extracts were washed with M aq HCl, aq NaCl, dried, and evaporated. The residue was chromatographed with 50:1 toluene–EtOAc to give 17 mg (62%) of **4**, identical with an authentic sample.

Methyl 6-O-*acetyl-2*-O-tert-*butoxy-3,4-dideoxy-3*-C-*nitro-α*-D-threo-*hex-3-enopyranoside* (**6**).—To a solution of **3** (30 mg, 0.10 mmol) in 1,4-dioxane (1 mL) was added *tert*-butyl hydroperoxide (0.5 mL) and then M NaOH (0.1 mL). After stirring for 3 min at room temperature, the mixture was partitioned between aq HCl and CH_2Cl_2. The extracts were washed with aq $Na_2S_2O_3$, aq satd NaCl, dried, and evaporated. The residue was again evaporated with toluene and then chromatographed with 100:1 toluene–EtOAc to give 30 mg (91%) of **6** as a syrup; $[\alpha]_D^{25}$ +7° (*c* 1.2, $CHCl_3$); ν_{max} 1745 (OAc) and 1535 cm^{-1} (NO_2); ^1H NMR: δ 5.30 (d, 1 H, $J_{1,2}$ 1.0 Hz, H-1), 4.97 (dd, 1 H, $J_{2,5}$ 2.0 Hz, H-2), 7.45 (d, 1 H, $J_{4,5}$ 2.0 Hz, H-4), 4.58 (tt, 1 H, $J_{5,6}$ 5.0, $J_{5,6'}$ 5.6 Hz, H-5), 4.40 (dd, 1 H, $J_{6,6'}$ 11.6 Hz, H-6), 4.33 (dd, 1 H, H-6′), 3.45 (s, 3 H, OMe), 2.10 (s, 3 H, OAc), and 1.23 (s, 9 H, Bu^t). Anal. Calcd for $C_{13}H_{21}NO_8$: C, 48.90; H, 6.63; N, 4.39. Found: C, 48.84; H, 6.56; N, 4.60.

Methyl 6-O-*acetyl-3,4-anhydro-2*-O-tert-*butoxy-3*-C-*nitro-α*-D-*talopyranoside* (**7**).—To a solution of **6** (30 mg, 0.09 mmol) in 1,4-dioxane (2 mL) was added MCPBA (purity 70%, 100 mg, 0.41 mmol) and then M NaOH (0.5 mL, 0.5 mmol). After stirring for 1 min, the mixture was partitioned between M aq HCl and CH_2Cl_2 (40 mL) and the organic layer was washed with aq $Na_2S_2O_3$, satd aq NaCl (twice), dried, and evaporated. The residue, from which toluene was again evaporated, was chromatographed with toluene and then 100:1 toluene–EtOAc to give 31 mg (98%) of **7** as a syrup. In

two-dimensional TLC, in which the second development was carried out after 30 min, no evidence for decomposition was observed, suggesting that the nitroepoxide **7** was fairly stable on silica gel; $[\alpha]_D^{25}$ +36° (*c* 0.9, CH_2Cl_2); ν_{max} 1750 (OAc), and 1570 cm^{-1} (NO_2); ^1H NMR: δ 4.73 (s, 1 H, H-1), 5.42 (s, 1 H, H-2), 3.79 (s, 1 H, H-4), 4.19 (t, 1 H, $J_{5,6} = J_{5,6'} = 5.9$ Hz, H-5), 4.27 (dd, 1 H, $J_{6,6'}$ 11.2 Hz, H-6), 4.39 (dd, 1 H, H-6′), 3.44 (s, 3 H, OMe), 2.12 (s, 3 H, Ac), and 1.24 (s, 9 H, Bu^t); ^{13}C NMR: δ 95.65 (C-1), 74.57 (C-2), 55.26 (C-4), 62.38 (C-5,6), 55.26 (OMe), 20.40 (CO*Me*), and 25.78 (*Me*$_3$C). NOE difference spectrum: H-1 (4%) signal appeared by irradiation at OMe. Assignment of these signals were confirmed by ^1H–^{13}C COSY. Anal. Calcd for $C_{13}H_{21}NO_9$: C, 46.57; H, 6.31; N, 4.18. Found: C, 46.83; H, 6.40; N, 4.45.

Methyl 6-O-acetyl-3-deoxy-3-C-nitro-α-D-talopyranoside (**8**).—A solution of **7** (100 mg, 0.30 mmol) in EtOH (100 mL) in the presence of Pd–C (100 mg) was shaken with H_2 at a pressure of 2 Kg/cm^2 at room temperature. After 11 h, the mixture was filtered and the filtrate was evaporated. The residue was chromatographed with 100:1 $CHCl_3$–MeOH to give 47 mg (59%) of **8** as a syrup; $[\alpha]_D^{25}$ +56° (*c* 1.0, MeOH); ν_{max} 3450 (br, OH), 1740 (OAc), 1550 cm^{-1} (NO_2); ^1H NMR: δ 4.92 (d, 1 H, $J_{1,2}$ 1.7 Hz, H-1), 4.50 (m, 1 H, H-2), 4.55 (t, 1 H, $J_{2,3} = J_{3,4} = 2.8$ Hz, H-3), 4.57 (m, 1 H, H-4), 4.00 (td, 1 H, $J_{4,5}$ 0.7, $J_{5,6}$ 6.3, $J_{5,6'}$ 6.6 Hz, H-5), 4.40 (dd, 1 H, $J_{6,6'}$ 11.2 Hz, H-6), 4.34 (dd, 1 H, H-6′), 3.77 (d, 1 H, $J_{2,OH}$ 8.3 Hz, OH at C-2, exchangeable by D_2O), 3.65 (d, 1 H, $J_{4,OH}$ 6.9 Hz, OH at C-4, exchangeable by D_2O), 3.43 (s, 3 H, OMe), and 2.11 (s, 3 H, OAc). NOE difference spectrum: H-3 (9%) and H-4 (6%) signals appeared by irradiation at H-5. Anal. Calcd for $C_9H_{15}NO_8$: C, 40.76; H, 5.70; N, 5.28. Found: C, 40.61; H, 5.82; N, 5.10.

Methyl 6-O-acetyl-2,3-anhydro-4-deoxy-3-C-nitro-α-D-lyxo- hexopyranoside (**9**).—A solution of **6** (20 mg, 0.06 mmol) in oxolane (3 mL) was cooled to −20°C, to which was added $NaBH_4$ (4 mg, 0.11 mmol). After stirring for 1 h, the mixture was partitioned between CH_2Cl_2 and M aq HCl. The organic layer was washed with aq NaCl, dried, and evaporated. The resulting residue was chromatographed with 50:1 toluene–EtOAc to give 15 mg (97%) of **9**; mp 57–57.5°C (Pr^{i}OH); $[\alpha]_D^{25}$ +100° (*c* 1.2, $CHCl_3$); ν_{max} 1730 (OAc), and 1560 cm^{-1} (NO_2); ^1H NMR (C_6D_6): δ 4.27 (s, 1 H, H-1), 3.23 (s, 1 H, H-2), 1.58 (dd, 1 H, $J_{4a,4e}$ 14.9 Hz, $J_{4a,5}$ 11.6 Hz, H-4*a*), 2.51 (dd, 1 H, $J_{4e,5}$ 4.3 Hz, H-4*e*), 3.60 (dq, 1 H, $J_{5,6}$ 5.0 Hz, H-5), 3.75 (d, 2 H, H-6,6′), 2.91 (s, 3 H, OMe), and 1.63 (s, 3 H, Ac). Anal. Calcd for $C_9H_{13}NO_7$: C, 43.73; H, 5.30; N, 5.67. Found: C, 43.83; H, 5.29; N, 5.47.

A similar reaction with $NaBD_4$ afforded the axially monodeuterated derivative **10** in high yield.

Methyl 6-O-acetyl-2,3-anhydro-4-deoxy-3-C-nitro-4-C-p-tolylthio-α-D-talopyranoside (**11**).—A solution of **6** (30 mg, 0.09 mmol) in CH_2Cl_2 (5 mL) was cooled to −30°C and *p*-toluenethiol (14 mg, 0.11 mmol) and a catalytic amount of Et_3N were added. The starting material **6** disappeared (TLC) within 1 min. Workup as described for **9** gave 33 mg (95%) of **11**; mp 157.5–158.5°C (Pr^{i}OH); $[\alpha]_D^{25}$ +91° (*c* 0.8, $CHCl_3$); ν_{max} (Nujol) 1740 (OAc), and 1560 cm^{-1} (NO_2); ^1H NMR (C_6D_6): δ 4.28 (s, 1 H, H-1), 3.30 (s, 1 H, H-2), 4.76 (d, 1 H, $J_{4,5}$ 3.6 Hz, H-4), 4.10 (ddd, 1 H, $J_{5,6}$ 7.3, $J_{5,6'}$ 5.0 Hz, H-5), 4.48 (dd, 1 H, $J_{6,6'}$ 11.6 Hz, H-6), 4.28 (dd, 1 H, H-6′), 2.93 (s, 3 H, OMe), 1.53 (s, 3 H, OAc), 1.94 (s, 3 H, SO_2Tol), 6.76 (br d, 2 H, Ph), and 7.45 (br d, 2 H, Ph). Anal.

Calcd for $C_{16}H_{19}NO_7S$: C, 52.02; H, 5.18; N, 3.79; S, 8.68. Found: C, 51.93; H, 5.37; N, 3.50; S, 8.48.

Methyl 6-O-acetyl-2,3-anhydro-4-deoxy-3-C-nitro-4-morpholino-α-D-talopyranoside (**12**).—A solution of **6** (20 mg, 0.06 mmol) in CH_2Cl_2 (3 mL) was cooled to −20°C and morpholine(0.5 mL, ~5.7 mmol) was added. The starting material **6** disappeared (TLC) within 1 min. Workup as described for **9** gave 17 mg (82%) of **12**; mp 68.5–69.5°C (Pr^iOH); $[\alpha]_D^{25}$ +102° (*c* 0.8, CH_2Cl_2); ν_{max} 1740 (OAc), and 1570 cm^{-1} (NO_2); ^1H NMR (C_6D_6): δ 4.24 (s, 1 H, H-1), 2.94 (s, 1 H, H-2), 4.10 (d, 1 H, $J_{4,5}$ 5.0 Hz, H-4), 3.98 (br dt, 1 H, $J_{5,6}$ 4.3, $J_{5,6'}$ 7.9 Hz, H-5), 4.27 (dd, 1 H, $J_{6,6'}$ 12.2 Hz, H-6), 4.20 (dd, 1 H, H-6′), 3.00 (s, 3 H, OMe), 1.72 (s, 3 H, OAc), 2.70 (m, 4 H, $NCH_2 \times 2$), and 3.35 (m, 4 H, $OCH_2 \times 2$). Anal. Calcd for $C_{13}H_{20}N_2O_8$: C, 46.99; H, 6.07; N, 8.43. Found: C, 46.70; H, 5.85; N, 8.70.

Methyl 6-O-acetyl-2,3-anhydro-4-O-methyl-3-C-nitro-α-D-talopyranoside (**13**).—To a solution of **6** (30 mg, 0.09 mmol) in MeOH (3 mL) was added a catalytic amount of 0.01 M LiOMe. The starting material **6** disappeared (TLC) within 7 h. Workup as described for **9** gave 11 mg (42%) of **13**; mp 123–124°C (Pr^iOH); $[\alpha]_D^{25}$ +98° (*c* 0.9, $CHCl_3$); ν_{max} 1750 (OAc), and 1560 cm^{-1} (NO_2); ^1H NMR: δ 4.98 (s, 1 H, H-1), 3.70 (s, 1 H, H-2), 4.94 (d, 1 H, $J_{4,5}$ 3.0 Hz, H-4), 4.10 (ddd, 1 H, $J_{5,6}$ 7.6, $J_{5,6'}$ 4.6 Hz, H-5), 4.24 (dd, 1 H, $J_{6,6'}$ 11.6 Hz, H-6), 4.34 (dd, 1 H, H-6′), 3.45 (s, 3 H, OMe), 3.47 (s, 3 H, OMe), and 2.10 (s, 3 H, OAc). Anal. Calcd for $C_{10}H_{15}NO_8$: C, 43.33; H, 5.45; N, 5.05. Found: C, 43.05; H, 5.19; N, 4.85.

Methyl 6-O-acetyl-2,3-anhydro-4-deoxy-4-C-diacetylmethyl-3-C-nitro-α-D-talopyranoside (**14**).—A solution of NaH (purity 55%, 8 mg, 0.18 mmol) in oxolane (4 mL) was stirred under N_2 and cooled to −20°C. To the solution was added 2,4-pentanedione (30 mg, 0.3 mmol) in oxolane (1 mL). After evolution of H_2 had ceased, a solution of **6** (30 mg, 0.09 mmol) in oxolane (1 mL) aws added. The starting material **2** disappeared (TLC) within 10 h. After addition of aq NH_4Cl, the mixture was extracted with EtOAc. The extracts were washed with aq satd NaCl, dried, and evaporated. The syrup was chromatographed with 10:1 toluene–EtOAc to give 15 mg (46%) of **14** as a syrup; $[\alpha]_D^{25}$ +148° (*c* 0.7, CH_2Cl_2); ν_{max} 1740 (OAc), 1700 (Ac), and 1570 cm^{-1} (NO_2); ^1H NMR: δ 4.85 (s, 1 H, H-1), 3.44 (s, 1 H, H-2), 4.43 (dd, 1 H, $J_{4,5}$ 2.6, $J_{4,4'}$ 9.6 Hz, H-4), 4.25 (ddd, 1 H, $J_{5,6}$ 7.6, $J_{5,6'}$ 5.3 Hz, H-5), 3.94 (dd, 1 H, $J_{6,6'}$ 11.9 Hz, H-6), 3.87 (dd, 1 H, H-6′), 4.32 (d, 1 H, H-4′, i.e., $CHAc_2$), 3.44 (s, 3 H, OMe), 2.08 (s, 3 H, OAc), 2.37 (s, 3 H, CAc), and 2.39 (s, 3 H, CAc). Anal. Calcd for $C_{14}H_{19}NO_9$: C, 48.70; H, 5.55; N, 4.06. Found: C, 49.00; H, 5.70; N, 4.35.

Reduction of **9** *with lithium aluminum hydride.*—To a stirred solution of **9** (50 mg, 0.20 mmol) in oxolane (5 mL) was added $LiAlH_4$ (150 mg, 3.95 mmol) at room temperature. After 1 h MeOH was added and the mixture was evaporated. The residue was chromatographed with 30:1 and 10:1 $CHCl_3$–MeOH to give 11.8 mg (36%) of **15** and 7.6 mg (23%) of **16** sequentially as syrups.

Compound **15**: $[\alpha]_D^{25}$ +145° (*c* 0.8, MeOH); ν_{max} 3400 (br, OH); ^1H NMR: δ 4.88 (br d, 1 H, $J_{1,2a}$ 3.6, $J_{1,2e}$ 1.7 Hz, H-1), 1.51 (ddd, 1 H, $J_{2a,2e}$ 12.5, $J_{2a,3}$ 11.6 Hz, H-2*a*), 2.11 (ddt, 1 H, $J_{2e,3}$ 4.6, $J_{2e,4e}$ 1.7 Hz, H-2*e*), 4.15 (tt, 1 H, $J_{3,4a}$ 11.2, $J_{3,4e}$ 4.6 Hz, H-3), 1.36 (ddd, $J_{4a,4e}$ 12.2, $J_{4a,5}$ 11.9 Hz, H-4*a*), 1.88 (ddt, 1 H, $J_{4e,5}$ 2.6 Hz, H-4*e*), 3.84 (ddt, 1 H, $J_{5,6}$ 3.0, $J_{5,6'}$ 6.6 Hz, H-5), 3.67 (dd, 1 H, $J_{6,6'}$ 11.6 Hz, H-6),

3.56 (dd, 1 H, H-6′), and 3.35 (s, 3 H, OMe). Anal. Calcd for $C_7H_{14}O_4$: C, 51.84; H, 8.70. Found: C, 51.92; H, 8.72.

Compound **16**: $[\alpha]_D^{25}$ +142° (*c* 0.6, MeOH); ν_{max} 3400 cm^{-1} (br, OH); ^1H NMR: δ 4.90 (br d, 1 H, $J_{1,2a}$ 3.3, $J_{1,2e}$ 1.3 Hz, H-1), 1.83 (dt, 1 H, $J_{2a,2e}$ 14.2, $J_{2a,3}$ 3.3 Hz, H-2*a*), 1.96 (dddd, 1 H, $J_{2e,3}$ 2.6, $J_{2e,4e}$ 1.3 Hz, H-2*e*), 4.10–4.13 (m, 2 H, H-3,5), 1.64 (ddd, 1 H, $J_{3,4a}$ 3.0, $J_{4a,4e}$ 13.5, $J_{4a,5}$ 11.2 Hz, H-4*a*), 1.72 (br d, 1 H, H-4*e*), 3.70 (dd, 1 H, $J_{5,6}$ 3.0, $J_{6,6'}$ 11.9 Hz, H-6), 3.58 (dd, 1 H, $J_{5,6'}$ 6.3 Hz, H-6′), and 3.42 (s, 3 H, OMe). Anal. Calcd for $C_7H_{14}O_4$: C, 51.84; H, 8.70. Found: C, 51.68; H, 8.81.

Similar reduction of **10** with $LiAlD_4$ afforded the corresponding trideuterio products (**17** and **18**). The equatorial and axial positions at C-2 and C-4, respectively, of both products were deuterated.

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