molecular structure with atom numbering is shown in Fig. 1. Bond lengths and angles are unexceptional (Allen, Kennard, Watson, Brammer, Orpen & Taylor, 1987; Duax & Norton, 1975).

The determination of absolute configuration of the C22 chiral centre, which turned out to be *S*, was based on the known chirality of the steroid framework. The main torsion angles, which characterize the molecular conformation, are given in Table 2. The steroid framework conformation coincides with a standard for $\Delta^{8(9)}$-pregnanes (Duax & Norton, 1975), *viz.* a chair for the *A* ring, a 5α-sofa for the *B* ring, a 13β-sofa for the *C* ring and a 14α-envelope for the *D* ring. The orientation of the side chain at C17, characterized by the torsion angle C16 C17 C20 C21 = −178·3°, may be considered as sterically least strained. The oxazoline ring is in fact planar. The orientation of the 3β-acetoxy group [with the carbonyl O and H(C3) atoms disposed close to each other] is similar to that usually observed in most of the analogous steroid derivatives (Duax & Norton, 1975).

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Structure of Propyl 3-Acetyl-4-[2-hydroxy-3-(isopropylamino)propoxy]carbanilate Hydrochloride

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Abstract. $C_{18}H_{29}N_2O_5^+.Cl^-$, $M_r = 388.9$, monoclinic, $C2/c$, $a = 42.014$ (8), $b = 5.054$ (1), $c = 30.023$ (5) Å, $\beta = 139.84$ (4)°, $V = 4111.4$ (6) Å^3, $Z = 8$, $D_m = 1.25$ (1), $D_x = 1.256$ Mg m^{-3}, λ(Cu $K\alpha$) = 1.54178 Å, $\mu = 0.94$ mm^{-1}, $F(000) = 1664$, $T = 293$ K, $R = 0.052$ for 1974 unique observed reflections. The structure consists of discrete cations connected by hydrogen-bonded chloride anions. The arrangement of the aryloxy and 2-hydroxyl groups around the conformationally flexible OCH_2—$CH(OH)CH_2$ bond of the oxypropanolamine side chain is *gauche*. While the lone-pair electrons of the ethereal oxygen are definitely delocalized through the adjacent phenyl ring, the results do not reveal any significant conjugation of the carbamate and acetyl groups with the aromatic system.

Introduction. This work is part of a more general study on conformational properties of a new series of β-adrenoceptor blocking drugs belonging to the aryloxypropanolamine family. Another interest in the present structure results from the observation that while the title compound is a highly potent β-adrenoceptor antagonist, its positional isomer, having interchanged the acetyl and carbamate functions on the aromatic ring, has been found to be totally inactive (Csöllei, Račanská, Švec & Kettmann, 1991). The inactivity of the latter was attributed to the positive molecular electrostatic potential (MEP) generated by the π-deficient phenyl ring as a result of through-conjugation between the ethereal oxygen and the acceptor acetyl group (Kettmann, 1991). Consequently, the structure deter-

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Table 1. *Final atomic coordinates* ($\times 10^4$) *and equivalent isotropic thermal parameters* (Å^2) *with e.s.d.'s in parentheses*

$B_{eq} = (4/3)\sum_i\sum_j \beta_{ij}\mathbf{a}_i.\mathbf{a}_j$.

	x	y	z	B_{eq}
C(1)	6833 (1)	4844 (5)	2741 (2)	3.62 (21)
C(2)	7254 (1)	3200 (5)	3192 (1)	3.49 (25)
C(3)	7593 (1)	3472 (6)	3897 (2)	3.87 (23)
C(4)	7527 (1)	5279 (5)	4170 (2)	3.84 (22)
C(5)	7116 (1)	6902 (6)	3720 (2)	4.66 (30)
C(6)	6774 (1)	6692 (6)	3017 (2)	4.54 (27)
C(7)	6029 (1)	5699 (6)	1575 (2)	4.14 (25)
C(8)	5739 (1)	4889 (5)	863 (2)	3.80 (24)
C(9)	5989 (1)	5644 (6)	703 (2)	4.13 (26)
C(10)	5976 (1)	4646 (6)	−134 (2)	4.69 (31)
C(11)	6258 (1)	2040 (7)	171 (2)	5.77 (33)
C(12)	5633 (2)	4891 (8)	−889 (2)	6.70 (41)
C(13)	7382 (1)	1191 (6)	2975 (2)	3.89 (24)
C(14)	7025 (1)	378 (6)	2244 (2)	4.45 (25)
C(15)	8109 (1)	3552 (6)	5340 (2)	4.86 (30)
C(16)	8699 (2)	2456 (9)	6518 (2)	8.44 (43)
C(17)	9108 (2)	3677 (15)	7187 (3)	13.35 (59)
C(18)	9457 (3)	5069 (21)	7303 (4)	19.81 (78)
N(1)	5686 (1)	4898 (4)	−14 (1)	3.61 (18)
N(2)	7876 (1)	5577 (5)	4886 (1)	4.41 (21)
O(1)	6511 (1)	4597 (4)	2052 (1)	4.34 (15)
O(2)	5681 (1)	2070 (4)	774 (1)	5.16 (23)
O(3)	7796 (1)	235 (5)	3420 (1)	5.69 (18)
O(4)	8046 (1)	1245 (4)	5190 (1)	7.94 (29)
O(5)	8426 (1)	4469 (4)	5981 (1)	5.57 (20)
Cl(1)	4964.1 (2)	9715 (1)	−875.8 (3)	4.54 (6)

Table 2. *Bond lengths* (Å) *and angles* (°) *with e.s.d.'s in parentheses*

C(1)—C(2)	1.411 (5)	C(10)—C(11)	1.523 (6)
C(2)—C(3)	1.386 (4)	C(10)—C(12)	1.498 (6)
C(3)—C(4)	1.390 (5)	C(2)—C(13)	1.508 (5)
C(4)—C(5)	1.384 (5)	C(13)—O(3)	1.220 (5)
C(5)—C(6)	1.377 (5)	C(13)—C(14)	1.482 (5)
C(6)—C(1)	1.390 (6)	C(4)—N(2)	1.405 (3)
C(1)—O(1)	1.358 (4)	N(2)—C(15)	1.350 (4)
O(1)—C(7)	1.425 (5)	C(15)—O(4)	1.204 (4)
C(7)—C(8)	1.498 (5)	C(15)—O(5)	1.332 (4)
C(8)—C(9)	1.502 (7)	O(5)—C(16)	1.458 (5)
C(8)—O(2)	1.436 (4)	C(16)—C(17)	1.445 (7)
C(9)—N(1)	1.486 (4)	C(17)—C(18)	1.409 (17)
N(1)—C(10)	1.513 (7)		

C(2)—C(1)—C(6)	119.2 (4)	C(9)—C(8)—O(2)	104.8 (3)
C(2)—C(1)—O(1)	117.8 (4)	C(8)—C(9)—N(1)	111.4 (3)
C(6)—C(1)—O(1)	123.0 (4)	C(9)—N(1)—C(10)	114.2 (3)
C(1)—C(2)—C(3)	118.6 (4)	N(1)—C(10)—C(11)	109.3 (4)
C(1)—C(2)—C(13)	125.5 (4)	N(1)—C(10)—C(12)	109.6 (4)
C(3)—C(2)—C(13)	115.9 (4)	C(11)—C(10)—C(12)	112.7 (4)
C(2)—C(3)—C(4)	122.1 (4)	C(2)—C(13)—O(3)	118.2 (4)
C(3)—C(4)—C(5)	118.4 (4)	C(2)—C(13)—C(14)	122.1 (4)
C(3)—C(4)—N(2)	121.9 (4)	O(3)—C(13)—C(14)	119.7 (4)
C(5)—C(4)—N(2)	119.7 (4)	C(4)—N(2)—C(15)	124.5 (4)
C(4)—C(5)—C(6)	120.9 (4)	N(2)—C(15)—O(4)	125.0 (5)
C(5)—C(6)—C(1)	120.9 (4)	N(2)—C(15)—O(5)	110.4 (4)
C(1)—O(1)—C(7)	119.5 (3)	O(4)—C(15)—O(5)	124.7 (5)
O(1)—C(7)—C(8)	108.0 (3)	C(15)—O(5)—C(16)	115.4 (4)
C(7)—C(8)—C(9)	112.6 (4)	O(5)—C(16)—C(17)	109.5 (6)
C(7)—C(8)—O(2)	111.9 (4)	C(16)—C(17)—C(18)	117.6 (9)

mination may help to clarify the electronic structure of the π-electron portion of the molecule and provide a structural basis for subsequent MEP calculation. In addition, this study offered us an opportunity to determine the hydrogen-bonding pattern of the protonated oxypropanolamine moiety with the Cl^- ions.

Experimental. Colourless single crystals obtained from aqueous ethanol solution, crystal used 0.4 × 0.35 × 0.1 mm; D_m by flotation in bromoform–cyclohexane; systematic absences, *hkl* for $h + k$ odd and *h0l* for *l* odd, from Weissenberg photographs; Syntex $P2_1$ diffractometer; unit-cell parameters by least-squares refinement of 15 reflections, $15 < \theta < 45°$; intensity data ($h = 0$ to 44, $k = 0$ to 5, $l = -31$ to 20) collected with graphite-monochromated Cu $K\alpha$ radiation, θ–2θ scan mode, variable scan speed, scan width 2° (in 2θ) plus $\alpha_1 - \alpha_2$ dispersion; two standards every 100 reflections: no appreciable changes; 2474 unique reflections, $2\theta_{max} = 110°$, 1974 with $I \geq 2\sigma(I)$ considered observed and included in the refinement; Lp correction but no correction for absorption or extinction; structure solved by direct methods using *MULTAN*80 (Main, Fiske, Hull, Lessinger, Germain, Declercq & Woolfson, 1980) and refined by block-diagonal least squares, $\Delta\rho$ map showed positions of all H atoms except those bonded to C(16)–C(18), refinement continued on all positional parameters, anisotropic thermal parameters for non-H atoms and isotropic thermal parameters for H atoms; in final cycle $R = 0.052$, $wR = 0.065$ for observed reflections only, $S = 1.51$, max. shift/e.s.d. = 0.12, function minimized $\sum w(\Delta F)^2$, where $w = 1$ if $|F_o| < 45$ and $w = 45/|F_o|$ if $|F_o| \geq 45$, to make $w(\Delta F)^2$ almost independent of $|F_o|$ and $\sin\theta$, max. and min. heights in final $\Delta\rho$ synthesis 0.17 and -0.14 e Å^{-3}; scattering factors for neutral atoms from *International Tables for X-ray Crystallography* (1974, Vol. IV); all calculations except *MULTAN* performed with the *XRC*83 program system (Pavelčík, Kettmann & Majer, 1985).

Discussion. Final atomic coordinates of non-H atoms and equivalent isotropic B's are listed in Table 1,* bond distances and angles in Table 2. The numbering scheme is shown in Fig. 1, which also displays the overall conformation of the molecule and corresponds to the biologically less active (*R*)-enantiomer.

From the pharmacological point of view the most important structural features of aryloxypropanolamines are the conformational properties of the oxypropanolamine side chain and the bonding characteristics of the aromatic terminus. The spatial relationship between the pharmacophoric groups, *i.e.*

* Lists of structure factors, anisotropic thermal parameters, H-atom parameters, least-squares planes and torsion angles have been deposited with the British Library Document Supply Centre as Supplementary Publication No. SUP 54403 (14 pp.). Copies may be obtained through The Technical Editor, International Union of Crystallography, 5 Abbey Square, Chester CH1 2HU, England.

the amino nitrogen, the 2-hydroxyl and the aromatic system, is defined by torsion angles at four potentially rotatable bonds: τ_1 = C(6)—C(1)—O(1)—C(7), τ_2 = C(1)—O(1)—C(7)—C(8), τ_3 = O(1)—C(7)—C(8)—C(9) and τ_4 = C(7)—C(8)—C(9)—N(1), which are −17.7 (4), −174.1 (2), −55.3 (3) and −178.0 (2)°, respectively. These data are consistent with the earlier observations of τ_1, τ_2 and τ_4 values in the crystal structures of aryloxypropanolamines, thus demonstrating a strong preference for these conformations (Kettmann & Csöllei, 1989).

The pattern of bond lengths and angles within the phenyl ring, which is of special interest to this study, is consistent with the ether O(1) atom alone taking part in the resonance of the phenyl ring (Domenicano, Murray-Rust & Vaciago, 1983). This suggestion that the acetyl and carbamate substituents are not involved, to any appreciable extent, in conjugation with the phenyl ring is further supported by their geometry. Thus, although the dihedral angle between the acetyl group and the phenyl-ring plane is relatively small (11.4°), the bond lengths within the acetyl group indicate localized single and double bonds, C(2)—C(13) [1.508 (5) Å] being even slightly longer than a normal $C(sp)^2$—$C(sp^2)$ single bond (1.487 Å; Shmueli, Shanan-Atidi, Horwitz & Shvo, 1973). The phenyl-ring–carbamate-group dihedral angle (φ) is 40.9° and the C_{ar}—N bond length is 1.405 (3) Å. Comparison with the corresponding values found previously for ethyl 2-[2-hydroxy-3-(isopropylamino)propoxy]carbanilate [16.7 (5)°, 1.406 (4) Å; Kettmann & Csöllei, 1989] shows that φ and C_{ar}—N are completely uncorrelated, implying that the electron-releasing power of the carbamate group is negligible. Indeed, examination of the crystal structures of alkyl *N*-arylcarbamates have revealed that the carbamate group occupies an intermediate position between acting as a π-electron donor and acceptor, and which of the two effects predominates depends on the (σ and π) charge and hence the substitution pattern of the phenyl ring (Laidlaw, Miura, Panetta & Metzger, 1988). In our series of compounds, having a slightly negatively charged phenyl ring owing to π donation from the ether oxygen, the carbamate group appears to have essentially no effect on the electron distribution of the phenyl ring, implying that the lone pair on the amide nitrogen is delocalized through conjugation with the ester group rather than with the phenyl ring.

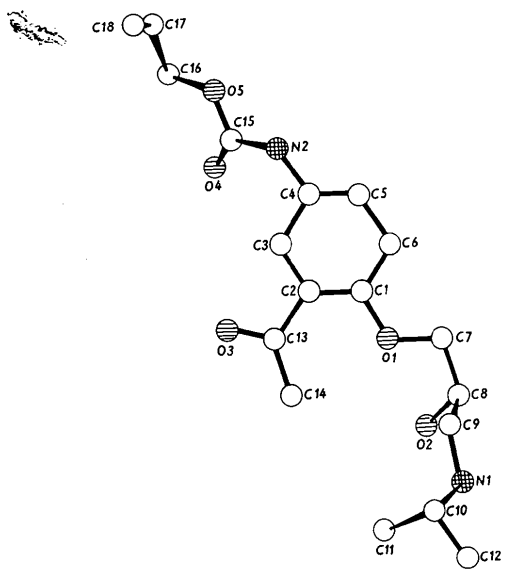

Fig. 1. A perspective view of the cation of the title compound and the numbering of the atoms.

The bond lengths and angles in other parts of the molecule are close to those generally expected except for the C(16)—C(17) and C(17)—C(18) bond lengths and the C(16)—C(17)—C(18) bond angle, which appear too shortened and widened, respectively, with respect to the standard values. This might be caused by a large libration of the *n*-propyl chain (about the chain axis) as evidenced by the high values of B_{eq} for C(16)–C(18), which increase on approaching the terminal C(18) methyl group.

Examination of the unit-cell packing reveals that while the oxypropanolamine chain is hydrogen bonded to three different Cl^- ions, the carbamate and acetyl groups are only loosely packed by weak van der Waals forces. The details of the geometry of these hydrogen bonds are: $N(1)^+$—H···Cl, N—H 0.91 (3), N···Cl 3.134 (4), H···Cl 2·26 (3) Å, N—H···Cl 160 (3)°; $N(1)^+$—H···Cl(x, $y-1$, z), N—H 0·85 (4), N···Cl 3·281 (3), H···Cl 2.47 (4) Å, N—H···Cl 157 (4)°; O(2)—H···Cl($1-x$, $1-y$, $1-z$), O—H 1.03 (8), O···Cl 3.081 (4), H···Cl 2.04 (8) Å, O—H···Cl 168 (5)°. It is of interest to note that the hydrogen-bonding pattern observed here is not the characteristic packing mode of the hydrochloride salts of β-adrenoceptor ligands not containing aromatic hydroxyl(s) (*e.g.* as in catecholamines) as competing hydrogen-bond donors. These compounds invariably prefer (the present structure is the first known exception) a simultaneous hydrogen bonding of OH and N^+H moieties to the common Cl^- anion, thus forming a seven-membered ring system. Such an interaction has also been shown to exist in solution (Zaagsma, 1979).

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Structure of 4-Nitroimidazole

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Abstract. $C_3H_3N_3O_2$, $M_r = 113.08$, monoclinic, $P2_1/c$, $a = 7.093$ (1), $b = 9.926$ (1), $c = 7.3474$ (9) Å, $\beta = 119.02$ (1)°, $V = 452.3$ (1) Å^3, $Z = 4$, D_m (293 K) = 1.63, $D_x = 1.66$ Mg m^{-3}, λ(Cu $K\bar{\alpha}$) = 1.54178 Å, $\mu = 1.18$ mm^{-1}, $F(000) = 232$, $T = 293$ K, final $R = 0.048$ for 702 unique observed reflections. Planar molecules of the 4-nitro tautomer (nitro group α to unprotonated N) are connected into ribbons along the **b** direction by N—H···N hydrogen bonds.

Introduction. Nitroimidazoles are known to be effective radiosensitizers either as uncoordinated groups (Farrell, 1989; Adams, Clarke, Flockhart, Jacobs, Sehmi, Stratford, Wardman, Watts, Parrick, Wallace & Smithen, 1979; Brown, Yu, Brown & Lee, 1984) or when incorporated in Pt, Ru and Rh complexes (Bales, Mazid, Sadler, Aggarwal, Kuroda, Neidle, Gilmour, Peart & Ramsden, 1985; Farrell, Carneiro, Einstein, Jones & Skov, 1984; Chan, Skov, James & Farrell, 1986; Goodgame, Lawrence, Slawin, Williams & Stratford, 1986). The influence of nitro groups on the coordinating properties of these ligands has so far received little attention. As part of our ongoing interest in metal complexes with nitroimidazoles, we first determined the structure of the free 4-nitro derivative. In contrast with other simple imidazoles, this compound does not readily form good crystalline material. Since disordering related to tautomeric forms coexisting in the crystal could not be ruled out as a possible explanation for this peculiarity, efforts were made to obtain a suitable material with which this question could be examined by X-ray diffraction.

Experimental. The compound was purchased from Aldrich Chemicals. It is much less soluble in all common solvents than imidazole and most of its derivatives. Attempts to grow crystals from water, dilute acids (HCl, HNO_3, H_2SO_4), alcohols, nitromethane and ethyl acetate, either by slow cooling of hot solutions or by slow evaporation of saturated solutions at room temperature, repeatedly produced microcrystalline or twinned materials. One crystallization in ethyl acetate yielded larger crystals, but oscillation photographs of many of them invariably showed twinning. With one specimen, the minor twin component appeared to be small enough not to give critical interference. The X-ray work was performed with this specimen.

Crystal size (pair of *hkl* faces): 0.14 (010/0$\bar{1}$0) × 0.19 (10$\bar{1}$/$\bar{1}$01) × 0.24 (100/$\bar{1}$00) mm. D_m measured by flotation in benzene–1,2-dibromoethane. Data collected on an Enraf–Nonius CAD-4 diffractometer with graphite-monochromatized Cu $K\bar{\alpha}$ radiation. Unit-cell dimensions determined from 25 centered reflections ($20 \le 2\theta \le 25°$). Laue symmetry and cell dimensions checked with long-exposure axial photographs along the three axes. No higher symmetry consistent with Niggli matrix. ω–2θ scan, $\omega = (0.80 + 0.14\tan\theta)°$, $2\theta_{max} = 140°$. Orientation monitored every 200 measurements, intensity checked every hour with six standard reflections, fluctuations within ±1.9%. 3355 reflections (eight octants) measured ($-8 \le h \le 8$, $-12 \le k \le 12$, $-8 \le l \le 8$). 853 independent *hkl* and *hk*$\bar{l}$ reflections after octant averaging ($R_{av} = 0.048$), 702 with $I \ge 1.96\sigma(I)$ retained for structure determination and refinement. Data corrected for Lp. No absorption correction applied.

Space group $P2_1/c$ uniquely defined by monoclinic Laue symmetry and systematic absences ($0k0$ $k \ne 2n$, $h0l$ $l \ne 2n$). All non-H atoms found by direct methods using *MULTAN*80 (Main, Fiske, Hull, Lessinger, Germain, Declercq & Woolfson, 1980). H atoms located from difference Fourier (ΔF) map.

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