Monatsh Chem (2010) 141:901–905
DOI 10.1007/s00706-010-0344-y

ORIGINAL PAPER

Selective reduction of 1,4-diarylimidazoline-3-oxides to imidazolidin-1-ols and hydroxylamine derivatives

Oktay Asutay · Necdet Coşkun

Received: 1 March 2010 / Accepted: 5 June 2010 / Published online: 27 July 2010

Abstract C-2-unsubstituted imidazoline-3-oxides were reduced with $NaBH_4$ in THF to give the corresponding *trans*-3,5-diarylimidazolidin-1-ols, while under the same conditions C-2-substituted derivatives gave the corresponding ring–chain–ring tautomers. Treatment of the crude reaction mixture from the reduction of C-2-unsubstituted imidazoline-3-oxides with a MeOH–H_2O mixture provided reductive C–N bond cleavage to give hydroxylamines, while under the same conditions ring–chain–ring tautomers remained unchanged.

Keywords Nitrones · Rearrangement · Ring–chain–ring tautomers · Selectivity · Hydroxylamine

Introduction

Recently we reported that 1,2,4-triarylimidazolin-3-oxides [1–3] **1** (R^1 = Ar) can be reduced with $NaBH_4$ in THF at reflux to give the corresponding 2,3,5-triarylimidazolidin-1-ols **2**, which proved to be in a ring–chain–ring tautomeric equilibrium with *N*-(2-aminoethyl) nitrones **3** and 3,5,6-triphenyl-1,2,5-oxadiazinanes **4** (Scheme 1) [4]. The ratios of the ring and chain form were determined by the substituent at the reaction center and described by the equation $\log K_X = \rho\sigma^+ + \log K_{X=H}$. A dynamic combinatorial library based on benzylidene exchange reactions of imidazolidin-1-ol, nitrone, and oxadiazinane ring–chain–ring tautomers at room temperature was created. The probable mechanism of the reaction was discussed based on Hammett-type correlation analyses [5]. To investigate the effect of substituents on the N-aromatic ring of **2a**–**4e** we have subjected a series of C-2-unsubstituted nitrones **1a**–**1e** to $NaBH_4$ reduction [6–9] in THF at reflux temperature, and the reduction products were proved to exist only in imidazolidin-1-ol forms **2a**–**2e**.

Here we report on the reduction of cyclic nitrones **1a**–**1e** to imidazolidine [10] derivatives **2a**–**2e**, which were selectively reduced to hydroxylamine derivatives **6a**–**6e** [11–14].

O. Asutay · N. Coşkun
Department of Chemistry, Muratlı Vocational School, Namık Kemal University, Muratlı-Tekirdağ, Turkey
e-mail: asutayoktay@yahoo.com

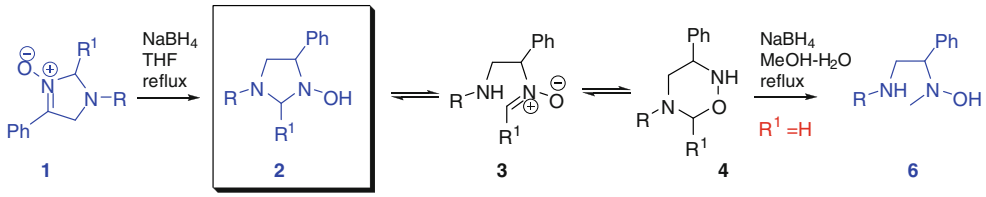
N. Coşkun (✉)
Department of Chemistry, Uludağ University, 16059 Bursa, Turkey
e-mail: coskun@uludag.edu.tr

Results and discussion

The reduction of cyclic nitrones **1a**–**1g** with $NaBH_4$ in THF provides the corresponding imidazolidin-1-ols **2a**–**2e** (Scheme 1) in the case of R^1 = H, and the corresponding ring–chain–ring tautomeric mixtures **2f**–**4g** [4, 5] in the case of R^1 = Ph.

The infrared (IR) spectra of compounds **2a**–**2e** (KBr) revealed the presence of OH stretching vibrations at ~3,250 cm^{-1}. Most of the peaks for the imidazolidine hydrogens in the ^1H nuclear magnetic resonance (NMR) spectra appear as broadened singlets instead of the expected patterns for AB and ABX systems. The hydroxyl hydrogen was seen in the case of **2d** at 6.08 ppm also as a broad singlet. Two of the imidazolidine ring protons resonate as doublet and triplet at ~4.49 and ~4.43 ppm, respectively; the heteronuclear multiple quantum coherence (HMQC) spectrum of **2a** shows that they belong to different carbons. One-dimensional (1D) nuclear Overhauser enhancement

Scheme 1



a: R = 4-MeO-C_6H_4, R^1 = H, **b**: R = 4-Me-C_6H_4, R^1 = H, **c**: R = C_6H_5, R^1 = H, **d**: R = 4-Br-C_6H_4, R^1 = H, **e**: R = 4-Cl-C_6H_4, R^1 = H, **f**: R = 4-MeO-C_6H_4, R^1 = Ph, **g**: R = 4-Me-C_6H_4, R^1 = Ph.

spectroscopy (NOESY) experiments revealed that the doublet is at C-2 while the triplet is at C-5. The NMR spectra of compounds **2** resembled those of nitrone–maleimide *endo* cycloadducts [15], where the presence of a radical center in the molecule causes pronounced broadenings of the neighboring atom signals. However, magnetic susceptibility measurements for **2a** did not confirm the presence of paramagnetic character of compounds **2**. Some assignments for imidazolidin-1-ols **2a**–**2e** [16–18] based on 1D and two-dimensional (2D) NMR experiments are exemplified for **2b** in Fig. 1.

X-ray crystallographic analysis of compound **2b** (Fig. 2) confirmed the assigned structure. The N2–O1 and O1–H distances are 1.447(5) and 0.880(5) Å, respectively, and are as usually found in similar structures. The N(1)–C(10) bond [1.451(6) Å] is slightly shorter than the N(2)–C(10) bond [1.455(5) Å]. Comparison of the N(1)–C(8) and N(2)–C(9) bonds reveals that the latter is longer than the former. All nitrogen-involving bonds except N(2)–C(9) are smaller than the usual value of 1.48 Å. The ring bond angles at N1, C(1)–N(1)–C(10) = 120.3(3)°, C(1)–N(1)–C(8) = 123.0(3)°, and C(10)–N(1)–C(8) = 109.6(3)°, are pointing to a nearly planar nitrogen. The bond angles at N2, C(10)–N(2)–O(1) = 106.0(3)° and C(9)–N(2)–O(1) = 107.5(3)°, are in agreement with a pyramidal nitrogen. The angles C(10)–N(2)–C(9) = 102.5(3)°, N(2)–C(9)–C(8) = 104.2(3)°, and C(9)–C(8)–N(1) = 102.9(3)° are shortened, while N(1)–C(10)–N(2) = 107.1(3)° and C(10)–N(1)–C(8) = 109.6(3)° are close to the usual tetrahedral angles. It is most noteworthy that the N(1) aromatic ring is coplanar with the plane of the imidazolidine ring [torsion angles involving the atoms C(10)–N(1)–C(1)–C(2) and C(8)–N(1)–C(1)–C(7) are 13.6(5)° and −21.3(6)°, respectively]. The torsion angle of 162.1(3)° for O(1)–N(2)–C(9)–C(11) clearly reveals the *trans* geometry of the molecule with respect to the hydroxyl at N(2) and the phenyl at C(9).

Compounds **2a**–**2e** were treated in toluene at room temperature with phenyl isocyanate to provide the O-carbamoylated products **5a**–**5e** [4]. The NMR characteristics of the latter are similar to those of compounds **2a**–**2e** with respect to the broadenings of the imidazolidine ring proton peaks (Fig. 1).

It is clear that compounds **2a**–**2g** are not reducible with $NaBH_4$ in THF; however, treatment of isolated C-2-unsubstituted **2** with the same reducing agent in MeOH–H_2O (2:1) provided selectively the compounds **6** within short time in excellent yield. The reduction of five-membered aminals was found to be dependent on the structural nature of the *N*,*N*′-substituents. The presence of an electron-deficient group appears to disfavor formation of the intermediate iminium ion and consequently lowers the rate of reduction [19].

Compounds **6a**–**6e** were prepared according to a one-pot procedure involving the treatment of compounds **1a**–**1e** with $NaBH_4$ in THF for 4 h and heating the crude reaction mixture in MeOH–H_2O (2:1) in a water bath for 0.5 h. We assume that compounds **6a**–**6e** arise from reduction of the ring-opened unstable nitrones **3a**–**3e**, although they do not form at room temperature in solvents such as $CDCl_3$ and

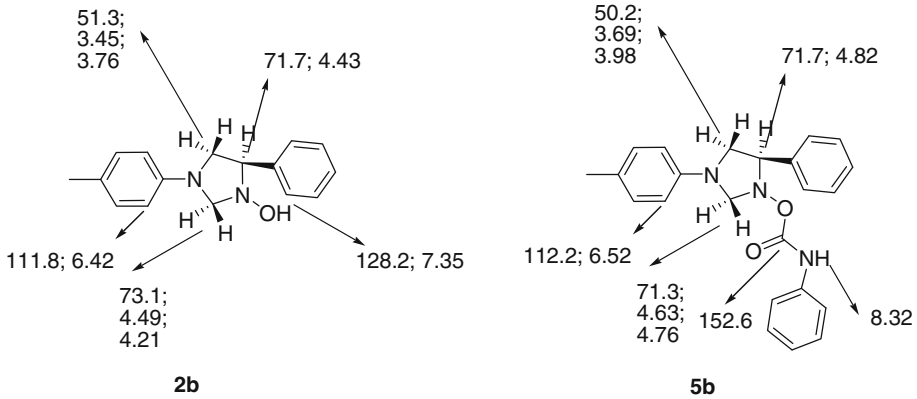


Fig. 1 Characteristic NMR data for **2b** and **5b**

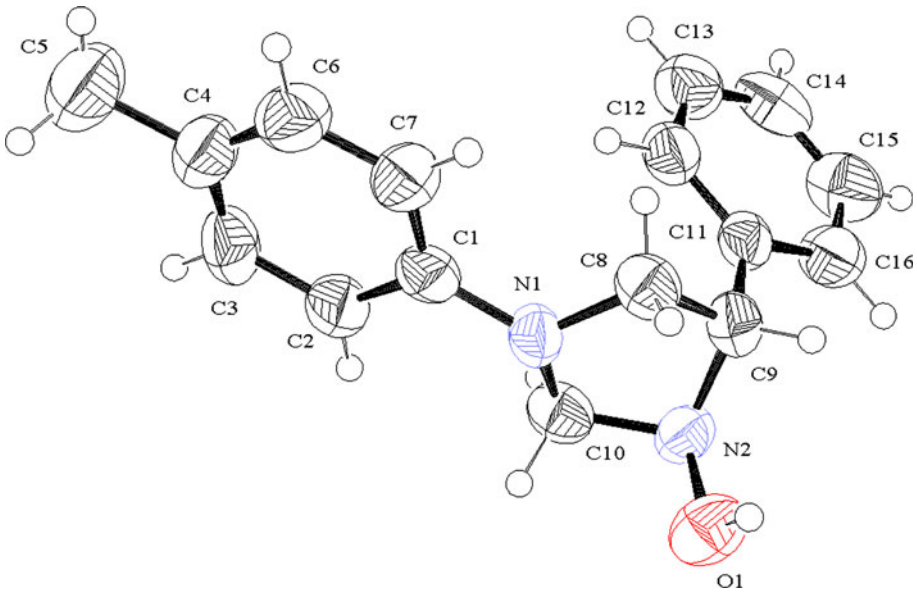


Fig. 2 X-ray crystal structure of compound **2b**, showing atom numbering scheme. *Thermal ellipsoids* are drawn at 50% probability level for clarity

dimethyl sulfoxide (DMSO)-d_6. Tautomeric mixtures **2f–4g** were treated with $NaBH_4$ in MeOH–H_2O (2:1) at reflux for 19 h. ^{1}H NMR investigations of the crude reaction mixtures revealed that no reduction products were formed. The starting materials were isolated and proved to be identical to the starting compounds **2f–4g**.

Experimental

Solvents and reagents were Aldrich or Merck quality and were used without additional purification. Melting points were taken using an electrothermal digital melting point apparatus. Infrared spectra were recorded on a Thermo-Nicolet 6700 FTIR. ^{1}H and ^{13}C NMR as well as 2D NMR experiments as correlation spectroscopy (COSY), HMQC, heteronuclear multiple-bond correlation (HMBC), and 1D NOESY were performed using a Varian Mercury Plus 400-MHz spectrometer. Elemental analyses were conducted using a EuroEA 3000 CHNS elemental analyzer. The results were found to be in good agreement (±0.2%) with the calculated values.

*General procedure for the synthesis of trans-3,5-diarylimidazolidin-1-ols **2a–2e***

To a solution of nitrone **1a–1e** (1.4 mmol) in 40 cm^3 THF, 0.5296 g $NaBH_4$ (14 mmol) was added, and the reaction mixture was refluxed under stirring for 4 h. The solvent was evaporated under vacuum, and the residue suspended in water and extracted with chloroform (2 × 15 cm^3). The combined extracts were washed with water (2 × 15 cm^3), dried over anhydrous Na_2SO_4, and filtered, and the solvent evaporated under reduced pressure. The nearly pure residue was crystallized from toluene/petroleum ether (ca. 1:5) at room temperature. The formed white crystals were filtered and dried under vacuum.

trans-3-(4-Methoxyphenyl)-5-phenylimidazolidin-1-ol (**2a**, $C_{16}H_{18}N_2O_2$)
Yield 0.303 g (80%); white crystals; m.p.: 107–108 °C; IR (KBr): $\bar{\nu}$ = 3,250 (N–OH) cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$): δ = 3.44 (1H, brs), 3.75 (3H, s), 3.76 (1H, brs), 4.27 (1H, brs), 4.43 (1H, t, J = 6.8 Hz), 4.49 (1H, d, J = 7.2 Hz), 6.48 (2H, d, J = 8.4 Hz), 6.86 (2H, d, J = 8.4 Hz), 7.32–7.39 (5H, m) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ = 55.9, 71.8, 72.0, 112.7, 115.1, 128.1, 128.6, 141.1, 151.7 ppm.

trans-3-(4-Methylphenyl)-5-phenylimidazolidin-1-ol (**2b**, $C_{16}H_{18}N_2O$)
Yield 0.285 g (80%); white crystals; m.p.: 123-124 °C; IR (KBr): $\bar{\nu}$ = 3,250 (N–OH) cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$): δ = 2.26 (3H, s), 3.44 (1H, brs), 3.76 (1H, brs), 4.21 (1H, brs), 4.39 (1H, t, J = 6.8 Hz), 4.49 (1H, d, J = 7.6 Hz), 6.42 (2H, d, J = 7.6 Hz), 7.06 (2H, d, J = 7.6 Hz), 7.35 (5H, s) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ = 20.4, 51.3 (CH_2), 71.7 (CH), 73.1 (CH_2), 111.8, 126.0, 128.2, 128.6, 129.3 ppm.

A colorless platelet crystal of **2b** ($C_{16}H_{18}N_2O$) having approximate dimensions of 0.60 × 0.40 × 0.10 mm^3 was mounted on a glass fiber. All measurements were made on a Rigaku RAXIS RAPID imaging plate area detector with graphite monochromated Mo K_α radiation. Cell constants and an orientation matrix for data collection corresponded to a primitive monoclinic cell with dimensions: a = 8.3634(3) Å, b = 9.9982(3) Å, c = 16.4784(6) Å, $\bar{\nu}$ = 1,377.90(8) Å^3, and β = 90.131(2)°. For Z = 4 and F.W. = 254.33, the calculated density is 1.23 g/cm^3. The

systematic absences of $h0l$: $h \pm 2n$ and $0k0$: $k \pm 2n$ uniquely determine the space group to be $P2_1/a$. Data were collected at temperature of 20 ± 1 °C to a maximum 2θ value of 50.2°. A total of 135 oscillation images were collected. The crystal-to-detector distance was 127.40 mm. Readout was performed in the 0.100-mm pixel mode.

trans-3,5-Diphenylimidazolidin-1-ol (**2c**, $C_{15}H_{16}N_2O$)
Yield 0.313 g (93%); white crystals; m.p.: 107–108 °C; IR (KBr): $\overline{\nu}$ = 3,250 (N–OH) cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$): δ = 3.48 (1H, brs), 3.81 (1H, brs), 4.30 (1H, brs), 4.44 (1H, brs), 4.57 (1H, d, J = 7.6 Hz), 6.52 (2H, d, J = 6.8 Hz), 6.75 (1H, d, J = 7.2 Hz), 7.24–7.26 (2H, m), 7.34–7.38 (5H, m) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ = 51.2, 71.6, 72.8, 111.7, 116.8, 127.9, 128.3, 128.7, 129.4, 137.9, 146.0 ppm.

trans-3-(4-Bromophenyl)-5-phenylimidazolidin-1-ol (**2d**, $C_{15}H_{15}BrN_2O$)
Yield 0.398 g (71%); white crystals; m.p. 120–122 °C; IR (KBr): $\overline{\nu}$ = 3,256 (N–OH) cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$): δ = 3.45 (1H, brs), 3.78 (1H, brs), 4.27 (1H, brs), 4.46 (1H, brs), 4.53 (1H, d, J = 7.6 Hz), 6.08 (1H, brs), 6.44 (2H, d, J = 7.6 Hz), 7.19 (2H, d, J = 7.6 Hz), 7.34–7.38 (5H, m) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ = 51.2, 71.6, 72.8, 112.7, 127.8, 128.3, 128.7, 129.2, 137.9, 146.0 ppm.

trans-3-(4-Chlorophenyl)-5-phenylimidazolidin-1-ol (**2e**, $C_{15}H_{15}ClN_2O$)
Yield 0.342 g (89%); white crystals; m.p.: 128 °C; IR (KBr): $\overline{\nu}$ = 3,243 (N–OH) cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$): δ = 3.45 (1H, brs), 3.78 (1H, brs), 4.27 (1H, brs), 4.47 (1H, brs), 4.54 (1H, d, J = 7.6 Hz), 6.40 (2H, d, J = 7.6 Hz), 7.33 (2H, d, J = 7.6 Hz), 7.34-7.38 (5H, m) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ = 51.2, 71.7, 72.6, 113.2, 114.2, 127.8, 128.3, 128.7, 132.0, 137.9, 145.0 ppm.

General procedure for the synthesis of phenylcarbamic acid 3,5-diarylimidazolidin-1-yl esters ***5a–5e***

To a solution of 3,5-diarylimidazolidin-1-ol **2** (0.3 mmol) in 30 cm^3 toluene was added 0.048 g phenyl isocyanate (0.4 mmol), and the reaction mixture was stirred at room temperature for 18 h. The solvent was evaporated under vacuum, and the residue dissolved in petroleum ether under heating and left to crystallize at room temperature.

Phenylcarbamic acid 3-(4-methoxyphenyl)-5-phenylimidazolidin-1-yl ester (**5a**, $C_{23}H_{23}N_3O_3$)
Yield 0.053 g (45%); white crystals; m.p.: 134 °C; IR (KBr): $\overline{\nu}$ = 3,299 (NH), 1,731 (C=O) cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$): δ = 3.66 (1H, brs), 3.78 (3H, s), 3.96 (1H, brs), 4.63 (1H, brs), 4.75 (1H, brs), 4.82 (1H, brs), 6.56 (2H, d, J = 8.4 Hz), 6.89 (2H, d, J = 8.4 Hz), 7.09–7.45 (10H, m), 8.32 (1H, brs, NH) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ = 50.9, 55.9, 71.4, 72.3, 113.2, 115.2, 115.4, 119.3, 124.2, 127.8, 128.9, 129.1, 136.8, 140.2, 152.2, 152.6 ppm.

Phenylcarbamic acid 3-(4-methylphenyl)-5-phenylimidazolidin-1-yl ester (**5b**, $C_{23}H_{23}N_3O_2$)
Yield 0.088 g (78%); white crystals; m.p.: 146 °C; IR (KBr): $\overline{\nu}$ = 3,300 (NH), 1,722 (C=O) cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$): δ = 2.29 (3H, s), 3.69 (1H, brs), 3.98 (1H, brs), 4.63 (1H, brs), 4.76 (1H, brs), 4.82 (1H, brs), 6.52 (2H, d, J = 8.0 Hz), 7.10 (2H, d, J = 8.0 Hz), 7.09–7.45 (10H, m), 8.31 (1H, brs, NH) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ = 20.4 (CH_3), 50.2 (CH_2), 71.3 (CH_2), 71.7 (CH), 112.2, 119.3, 124.2, 126.9, 127.8, 128.9, 129.1, 130.0, 136.8, 143.4, 152.6 ppm.

Phenylcarbamic acid 3,5-diphenylimidazolidin-1-yl ester (**5c**, $C_{22}H_{21}N_3O_2$)
Yield 0.055 g (51%); white crystals; m.p.: 121 °C; IR (KBr): $\overline{\nu}$ = 3,298 (NH), 1,724 (C=O) cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$): δ = 3.72–3.75 (1H, m), 4.01 (1H, brs), 4.66 (1H, brs), 4.79–4.86 (2H, m), 6.59 (2H, d, J = 8.0 Hz), 6.82 (1H, d, J = 8.0 Hz), 7.10–7.45 (12H, m), 8.32 (1H, brs, NH) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ = 50.9, 71.3 (2C), 112.1, 117.0, 119.3, 124.2, 127.8, 128.9, 129.1, 129.5, 136.8, 152.6 ppm.

Phenylcarbamic acid 3-(4-bromophenyl)-5-phenylimidazolidin-1-yl ester (**5d**, $C_{22}H_{20}BrN_3O_2$)
Yield 0.114 g (86%); white crystals; m.p.: 114 °C; IR (KBr): $\overline{\nu}$ = 3,335 (NH), 1,741 (C=O) cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$): δ = 3.72 (1H, brs), 3.98 (1H, brs), 4.61 (1H, brs), 4.73 (1H, brs), 4.85 (1H, brs), 6.46 (2H, d, J = 8.4 Hz), 7.09–7.45 (12H, m), 8.24 (1H, brs, NH) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ = 51.2, 71.2 (2C), 110.0, 113.6, 119.3, 124.3, 127.7, 129.1, 132.2, 136.7, 144.4, 152.4 ppm.

Phenylcarbamic acid 3-(4-chlorophenyl)-5-phenylimidazolidin-1-yl ester (**5e**, $C_{22}H_{20}ClN_3O_2$)
Yield 0.060 g (51%); white crystals; m.p.: 111 °C; IR (KBr): $\overline{\nu}$ = 3,335 (NH), 1,742 (C=O) cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$): δ = 3.73 (1H, brs), 3.99 (1H, brs), 4.61 (1H, brs), 4.74 (1H, brs), 4.85 (1H, brs), 6.51 (2H, d, J = 8.4 Hz), 7.09–7.40 (12H, m), 8.24 (1H, brs, NH) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ = 51.2, 71.3 (2C), 113.1, 119.3, 124.3, 127.7, 129.1, 129.3, 136.7, 144.4, 152.4 ppm.

General procedure for the synthesis of N-(2-arylamino-1-phenylethyl)-N-methylhydroxylamines ***6a–6e***

To a solution of nitrone **1** (1.4 mmol) in 40 cm^3 THF, $NaBH_4$ (14 mmol) was added and the reaction mixture was

refluxed under stirring for 4 h. The solvent was evaporated under vacuum, the residue dissolved in 10 cm^3 water and 20 cm^3 methanol, and the mixture stirred under reflux for 0.5 h. The solvent was evaporated under vacuum, and the residue extracted with chloroform (2×15 cm^3). The combined extracts were dried over Na_2SO_4 and filtered, and the solvent evaporated. The residue was dissolved in ether/petroleum ether mixture (10 cm^3, 2:1) and left to crystallize in a refrigerator.

N-[2-(4-Methoxyphenylamino)-1-phenylethyl]-N-methylhydroxylamine (**6a**, $C_{16}H_{20}N_2O_2$)
Yield 0.290 g (76%); white crystals; m.p.: 87 °C; IR (KBr): $\bar{\nu} = 3{,}365$ (NH), 3,243 (N–OH) cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$): $\delta = 2.53$ (3H, s), 3.38 (1H, dd, $J = 14.4$, 8.0 Hz), 3.74 (3H, s), 3.76–3.81 (2H, m), 6.57 (2H, d, $J = 9.2$ Hz), 6.76 (2H, d, $J = 9.2$ Hz), 7.31–7.37 (5H, m) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): $\delta = 46.4$ (CH_3), 48.3 (CH_2), 55.8 (CH_3O), 72.3 (CH), 114.7, 114.9, 128.1, 128.8, 142.1, 152.3 ppm.

N-Methyl-N-[2-(4-methylphenylamino)-1-phenylethyl]hydroxylamine (**6b**, $C_{16}H_{20}N_2O$)
Yield 0.319 g (89%); white crystals; m.p.: 113–114 °C; IR (KBr): $\bar{\nu} = 3{,}384$ (NH), 3,199 (N–OH) cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$): $\delta = 2.31$ (3H, s), 2.53 (3H, s), 3.36–3.42 (1H, m, part of an ABC system), 3.76–3.83 (2H, m, part of an ABC system), 6.53 (2H, d, $J = 8.8$ Hz), 6.97 (2H, d, $J = 8.8$ Hz), 7.31–7.37 (5H, m) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): $\delta = 20.4$ (CH_3), 46.3 (CH_3), 47.6 (CH_2), 72.2 (CH), 113.4, 126.9, 128.1, 128.6, 128.8, 129.8, 138.0, 145.6 ppm.

N-Methyl-N-[1-phenyl-2-(phenylamino)ethyl]-hydroxylamine (**6c**, $C_{15}H_{18}N_2O$)
Yield 0.258 g (76%); white crystals; m.p.: 118–119 °C; IR (KBr): $\bar{\nu} = 3{,}387$ (NH), 3,195 (N–OH) cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$): $\delta = 2.54$ (3H, s), 3.40–3.44 (1H, dd, $J = 14.4$, 8.0 Hz), 3.78–3.86 (2H, m), 4.01 (1H, brs), 6.60 (2H, d, $J = 8.0$ Hz), 6.70 (1H, t, $J = 8.0$ Hz), 7.16 (2H, t, $J = 8.0$ Hz), 7.32–7.37 (5H, m) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): $\delta = 46.4$ (CH_3), 47.2 (CH_2), 72.2 (CH), 113.2, 117.6, 128.2, 128.7, 128.8, 129.3, 138.0, 147.9 ppm.

N-[2-(4-Bromophenylamino)-1-phenylethyl]-N-methylhydroxylamine (**6d**, $C_{15}H_{17}BrN_2O$)
Yield 0.279 g (62%); white crystals; m.p. 135 °C; IR (KBr): $\bar{\nu} = 3{,}387$ (NH), 3,206 (N–OH) cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$): $\delta = 2.53$ (3H, s), 3.36-3.40 (1H, m), 3.75–3.80 (2H, m), 4.04 (1H, brs, NH), 6.10 (1H, brs, OH), 6.47 (2H, d, $J = 8.0$ Hz), 7.22 (2H, d, $J = 8.0$ Hz), 7.29–7.37 (5H, m) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): $\delta = 46.5$ (CH_3), 47.2 (CH_2), 72.1 (CH), 109.1, 114.7, 128.3, 128.7, 132.0 (2C), 138.0, 146.9 ppm.

N-[2-(4-Chlorophenylamino)-1-phenylethyl]-N-methylhydroxylamine (**6e**, $C_{15}H_{17}ClN_2O$)
Yield 0.263 g (68%); white crystals; m.p.: 134 °C; IR (KBr): $\bar{\nu} = 3{,}385$ (NH), 3,197 (N–OH) cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$): $\delta = 2.53$ (3H, s), 3.37–3.40 (1H, m), 3.75–3.82 (2H, m), 4.04 (1H, brs), 6.50 (2H, d, $J = 8.0$ Hz), 7.08 (2H, d, $J = 8.0$ Hz), 7.29–7.37 (5H, m) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): $\delta = 46.5$ (CH_3), 47.2 (CH_2), 72.2 (CH), 114.2, 122.1, 128.3, 128.7, 128.8, 129.1, 137.8, 146.5 ppm.

Acknowledgments Uludağ University Research Fund is gratefully acknowledged for its financial support (project no. 2001-2).

References

1. Coşkun N, Asutay O (1999) Chim Acta Turc 27:17
2. Coşkun N, Asutay O (1997) Chim Acta Turc 25:69
3. Coşkun N, Çetin M (2006) Tetrahedron 65:648
4. Coşkun N, Asutay O (2007) Tetrahedron Lett 48:5151
5. Coşkun N, Aksoy Ç (2009) Tetrahedron Lett 50:3008
6. Smith LI (1938) For the synthesis and reactions of nitrones. Chem Rev 23:193
7. Hamer J, Macaluso A (1964) Chem Rev 64:473
8. Spence GG, Taylor EC, Buchardt O (1970) Chem Rev 70:231
9. Gothelf KV, Jorgensen KA (1998) Chem Rev 98:863
10. Ferm RJ, Riebsomer JL (1954) For general methods for the synthesis of imidazolidines. Chem Rev 54:593
11. Stanek J, Frei J, Mett H, Schneider P, Regenass U (1992) J Med Chem 35:1339
12. Sosnovskikh VY, Moshkin VS, Kodess MI (2008) Tetrahedron 64:7877
13. Filimonov SI, Filimonova SA, Shashkov AS, Firgang SI, Stashina GA (2006) Mendeleev Commun 16:328
14. Smith DG, Gribble AD, Haigh D, Ife RJ, Lavery P, Skett P, Slingsby BP, Stacey R, Ward RW, West A (1999) Bioorg Med Chem Lett 9:3137
15. Coşkun N, Öztürk A (2007) Tetrahedron 63:1402
16. Osiecki JH, Ullman EF (1968) J Am Chem Soc 90:1078
17. Keana JFW (1978) Chem Rev 78:37
18. Kroll C, Schwarz KH, Surmann P, Borchert HH (1999) Bioelectrochem Bioenerg 48:233
19. Boyd E, Coumbarides GS, Eames J, Jones RVH, Stenson RA, Suggate MJ (2005) Tetrahedron Lett 46:3479