Journal of the Korean Chemical Society
2009, *Vol. 53, No. 1*
Printed in the Republic of Korea

4-(2-Chloroethyl) semicarbazide의 히드라존 유도체 합성 : 새로운 종류의 세포독성요법제

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(2008. 10. 26 접수)

Synthesis of Hydrazone Derivatives of 4-(2-Chloroethyl) semicarbazide : A New Class of Cytotoxic Agents

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(Received Octorber 26, 2008)

요　약. 새로운 종류의 히드라존 유도체는 4-(2-chloroethyl) semicarbazides로 부터 합성되었고, 인간 두뇌(U251)와 간(Hepg2)의 암세포 에 대해 항증식성을 보였다. 히드라존 화합물은 벤즈알데히드, 아세토페논, 3-formylindole 유도체이다. 아세토페논 유도체중에 **3e** (*p*-methoxy substituted)와 and **3f** (*p*-nitro substituted)는 Hepg2 세포 (각각IC_{50} = 6 ,8 μg/mL) 에 대해 가장 높은 세포독성활성을 보인다. 3-Formylindole 유도체중에 **4a** (hydrazone of 3-formylindole)은 U251 (IC_{50} = 21 μg/mL)와 Hepg2 (IC_{50} = 7 μg/mL)에 강한 세포독성활성을 보인다.

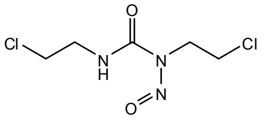
주제어: 히드라존, 2-(Chloroethyl)요소들, 4-(2-Chloroethyl) semicarbazides, 세포독성요법 활성

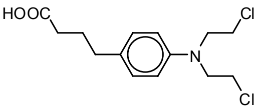
ABSTRACT. A new series of hydrazone derivatives were synthesized from 4-(2-chloroethyl)semicarbazide and their antiproliferative activity against human brain (U251) and liver (Hepg2) carcinoma cell lines were evaluated. The hydrazone compounds are benzaldehyde (**2a-2g**), acetophenone (**3a-3f**), and 3-formylindole derivatives (**4a-4d**). Among the acetophenone derivatives, **3e** (*p*-methoxy substituted) and **3f** (*p*-nitro substituted) showed the highest cytotoxic activity against Hepg2 cell line (IC_{50} = 6 and 8 μg/ml, respectively). Among the 3-formylindole derivatives, **4a** (hydrazone of 3-formylindole itself) showed a pronounced cytotoxic activity against both U251 (IC_{50} = 21 μg/ml) and Hepg2 (IC_{50} = 7 μg/ml).

Keywords: Hydrazones, 2-(Chloroethyl)ureas, 4-(2-Chloroethyl) semicarbazides, Cytotoxic activity

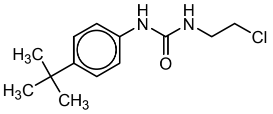
INTRODUCTION

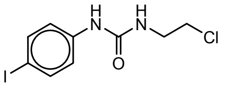
1-Aryl-3-(2-chloroethyl)ureas (CEUs) were found to exhibit better cytotoxicity[1] than the parent drugs *i.e.* chlorambucil and carmustine.[2-6] These derivatives as for examples 1-(4-tert-butylphenyl)-3-(2-chloroethyl) urea (A) and 1-(4-Iodophenyl)-3-(2-chloroethyl) urea (B) were designed as hybrid based on the conjugation of aromatic ring of chlorambucil as the prosthetic group and the cytotoxic 2-chloroethylnitrosourea moiety of carmustine as the pharmacophore.[7]

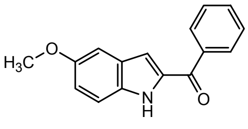

carmustine


chlorambucil

The SAR of the CEU derivatives showed that the unnitrosated derivatives were the only active ones; meanwhile, the exocyclic urea function and the 2-chloroethyl group were essential for activity; moreover, the preferred aryl groups were 4-substituted phenyl with alkyl or an indanyl group.[8] This class was found to irreversibly alkylate β-tubulin inside the cancer cell causing the cytotoxic effect.[9] Unfortunately, these derivatives caused many side effects such as developing resistance through P-glycoprotein overexpression and modification of topoisomerase I.[10]

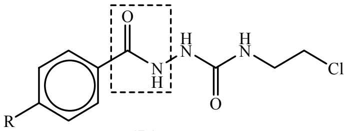

(A)


(B)

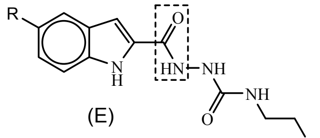

(C)

On the other side, a series of synthetic indole derivatives[11,12] such as compound D-64131(C) have proven to have significant antitumoral activity both in *vitro* and *in vivo*.

In our previous work, a series of benzamides (D) and 2-indolecarboamides (E) derivatives of the 4-(2-chloroethyl)semicarbazide were prepared[13] as a new class of cytotoxic agents. These derivatives were structurally related to 1-aryl-3-(2-chloroethyl) ureas derivatives with some structural variations whereas the aryl moiety whether *p*-substituted phenyl (D) or 5-substituted indolyl (E) was linked indirectly to (2-chloroethyl)urea function through carbonylamino moiety. It was found that semicarbazides containing 2-indolyl carbonyl moiety (E) especially those having electron-donor substituents at position 5 of the indole ring like methoxy (IC_{50} = 8 μg/ml against U251) and benzyloxy (IC_{50} = 21 μg/ml against Hepg2) showed a higher cytotoxic activity than their corresponding benzoyl derivatives(D) against human brain (U251) and liver (Hepg2)carcinoma cell lines.


(D)

R = H,CH_3,F,Cl,OCH_3,$OCH_2C_6H_5$, NO_2


(E)

R = H,F,Cl,OCH_3,$OCH_2C_6H_5$

In continuation to our previous work, a new series of hydrazone derivatives belonging to *p*-substituted benzaldehyde or *p*-substituted acetophenone were synthesized from 4-(2-chloroethyl) semicarbazide to study, firstly, the effect of different substituents on the cytotoxic activity. Secondly, we studied also the effect of replacement of *p*-substituted phenyl belonging to benzaldehyde hydrazone of the 4-(2-chloroethyl)semicarbazide by 5-substituted indolyl moieties upon the resultant cytotoxic activity against human brain and liver carcinoma cell lines.

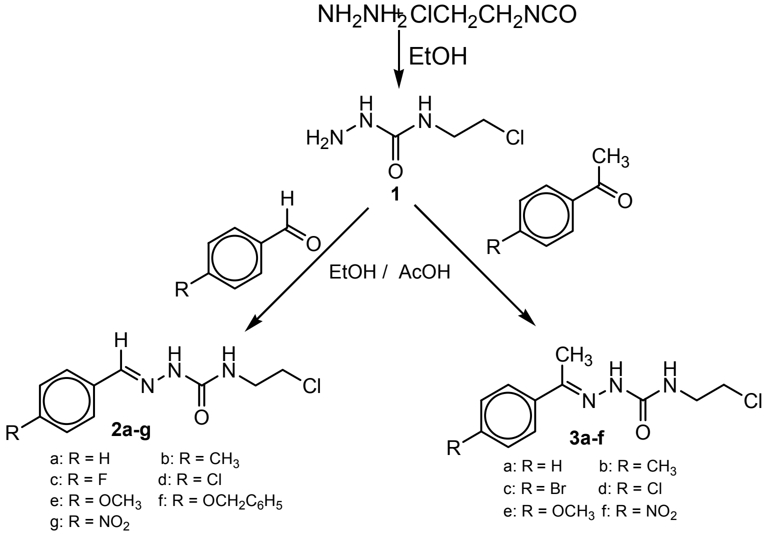
Discussions

A) Chemisrty

To achieve the first aim, a new series of hydrazones derived from *p*-substituted benzaldehyde **(2a-g)** and *p*-substituted-acetophenone (**3a-f**) were prepared as shown in *Scheme 1.*

The novel and valuable key intermediate, 4-(2-chloroethyl) semicarbazide intermediate (**1**), was prepared for the first time by adding 2-chloroethyl isocyanate dropwise to excess hydrazine hydrate in ethanol. Both the sequence of addition and room temperature were very important in order to minimize the formation of the expected side products. The intermediate **1** should be used directly in the next step, because it is very hygroscopic. Its structure was confirmed using the elemental analyses and mass spectroscopy.

The novel hydrazone derivatives of the 4-(2-chloroethyl)semicarbazide **2a-g** or **3a-f** were pre-

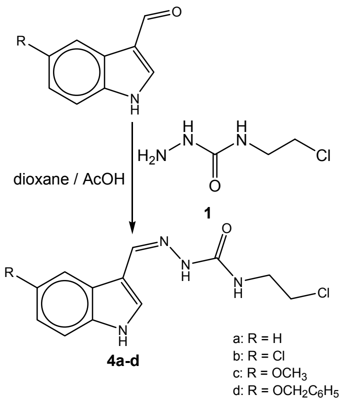


Scheme 1

pared by condensation of intermediate **1** with the corresponding *p*-substituted benzaldehyde or acetophenones in ethanol containing few drops of glacial acetic acid (*Scheme 1*).

To achieve the second aim, *p*-substituted phenyl of benzaldehyde hydrazone (**2**) was replaced by 5-substituted indolyl moiety at position 1 of the semicarbazide (**4**) as shown in *Scheme* 2.

Thus, the novel 1-[(5-substituted-1H-indol-3-yl)methylidene]-4-(2-chloro ethyl)semicarbazides (**4a-d**) were synthesized by stirring the intermediate **1** with the corresponding 5-substituted-1H-indole-3-carboxaldehyde in dioxane [14] containing few drops of glacial acetic acid at room temperature for two hours.



Scheme 2

The new compounds were characterized using melting points and thin layer chromatography techniques in different solvent systems. Moreover, the structures of the novel compounds were determined using elemental analyses and various spectral data. From the mass spectra, the absence of molecular ion peaks for compounds **2b**, **4c**, **4d** and the appearance of M^+ - HCl (M^+ - 36.5) peaks were observed, indicating the instability of molecular ion peak which undergoes rapid fragmentation and also the low relative intensity of such peak in some compounds such as **2a** (3.8%) and **4b** (5.9%).

The structure of some compounds as for example **4d** which showed M^+ -36.5 peak in the mass spectra was established using ^{1}H-NMR. It confirmed the presence of straight chain for chloroethyl semicarbazide moiety through appearance of two peaks at various chemical shift 3.52 and 3.69 ppm for the two methylene groups as well as the appearance of two peaks at 6.78 and 10.05 ppm for the NH groups in addition to singlet peak at 8.07 ppm due to azomethine proton.

B) Cytotoxic evaluation

The new compounds **2a-g**, **3a-f** and **4a-d** were evaluated for their *in vitro* cytotoxic activity against human brain (U251) and liver carcinoma (Hepg2)

Table 1. Cytotoxic evaluation for compounds **2**a-g, **3**a-f and **4**a-d against U251 and Hepg2.

IC_{50}[a] (μg/ml)					
Compound	U251	Hepg2	Compound	U251	Hepg2
2a	35	28	**3c**	39	95
2b	25	65	**3d**	73	NA
2c	35	26	**3e**	72	6
2d	38	NA[b]	**3f**	NA	8
2e	40	80	**4a**	21	7
2f	30	40	**4b**	65	NA
2g	NA	32	**4c**	28	63
3a	87	52	**4d**	21	16
3b	42	95			

[a] IC_{50}: Dose which required to inhibit cell growth by 50%.
[b] NA: not active i.e., it has IC_{50} more than 100 μg/ml.

cell lines as well as their structure activity relationship (SAR) were studied. These targets were evaluated at four concentration values (10, 25, 50, 100 μg/ml) using the sulforhodamine B (SRB) assay[15] and the results were displayed in *Table* 1. Given compounds were considered significantly active when their IC_{50} values were lesser than 100 μg/ml.

It was observed through analysis of table 1 that variable results were obtained depending not only on the type of the used cell line but also on the type of substitution at position 1 of the semicarbazides as seen in comparison of hydrazone derived from benzaldehyde **(2a-g)** with that of acetophenone **(3a-f)**.

Firstly, regarding the U251 cell line, it could be concluded that cytotoxic activity has been increased in the order **3** < **2** as seen in comparison of the unsubstituted or methyl or chloro derivatives belonging to the general formulas **3** with that of **2**.

Secondly, for Hepg2 cell line, the cytotoxic activity has increased in the order **2** < **3** as observed from IC_{50} values for compounds **3e** (6 *ug/ml*) and **3f** (8 *ug/ml*) which showed the higher cytotoxic activity than their corresponding **2** derivatives**.**

Table 1 revealed that replacement of phenyl ring of the parent compound **2a**, (IC_{50} = 35 *ug/ml* against U251 and 53 *ug/ml* against Hepg2) by indole moiety as seen in compound **4a**, (IC_{50} = 21 *ug/ml* against U251 and 7 *ug/ml* against Hepg2) led to an increase in the cytotoxic activity against the assigned cell lines. The last phenomena was also observed upon comparing the IC_{50} values for compounds **2e**, **2f** which have an electron donating substituents with their corresponding indole derivatives **4c**, **4d**. Thus, hydrazones **4a**, **4c**, **4d** containing an indole moiety were more active than their corresponding *p*-substituted phenyl derivatives**.**

It was also found that all chloro derivatives **2d**, **3d** and **4b** have no cytotoxic activity upon Hepg2 which could arise from biochemical variations between different cancer cell phenotypes.

CONCLUSIONS

The main objective of this study was to synthesize new hydrazone derivatives of 4-(2-chloroethyl)semicarbazide and exploration of their potential cytotoxic activity.

SAR studies revealed that:

- Regarding human brain carcinoma cell line, the hydrazones of the 4-(2-chloroethyl)semicarbazide derived from *p*-substituted benzaldehyde especially derivative **2b** exhibited the highest cytotoxic activity while in case of human liver carcinoma cell line, hydrazones **3e, 3f** belonging to acetophenone gave the highest cytotoxic activity.
- It could be concluded that replacement of *p*-substituted phenyl group of benzaldehyde hydrazones **(2a**, **2e**, **2f)** by indole moiety **(4a**, **4c**, **4d)** led to enhancement of the cytotoxic activity against the assigned cell lines.
- It was also found that semicarbazide **4a** bearing an indole moiety was the most active one against the two cell lines and recommended for further future optimization to be potential candidate for new anticancer agents.

EXPERIMENTAL

A) Chemistry

Materials and Methods

Melting points were determined with a Gallenkamp digital melting point apparatus in open capillaries and are uncorrected. IR spectra (KBr, cm^{-1}) were recorded on Bruker or Testscan Shimadzu FT 8000 spectrometer. ^{1}HNMR spectra were determined on a *Varian Gemini* 90 and a Bruker AC. 200 MHz instrument using DMSO-d_6 as a solvent and *TMS* as an internal standard (chemical shifts in δ, ppm). Mass spectra were measured on a GCMS-QP1000EX-SHIMADZU with an ionization energy equals to 70 eV. Elemental analyses were determined using Heraew and Vario EL-III (Elemntar), CHNS analyzer (Germany) at Microanalytical Center, (Faculty of Science, Cairo University) and National Researches Centre, Egypt. All the results of elemental analyses corresponded to the calculated values within experimental error. TLC was performed on silica gel G (Fluka), and spots were visualized by UV irradiation (254 nm). Starting materials were purchased from Lancaster Synthesis Corporation (U.K.).

1. 4-(2-chloroethyl) semicarbazide. A solution of 2-chloroethylisocyanate (10 mmol) in EtOH (10 ml) was added dropwise to a stirred solution of hydrazine hydrate (15 mmol) in EtOH (20 ml). The resulting solution was stirred at rt for 12 h. The separated precipitate was dissolved in $CHCl_3$ and then filtered over anhydrous Na_2SO_4. The dried chloroformic solution was added to equal volume of petroleum ether (60-80) which led to separation of white precipitate in the form of clusters. The intermediate **1** was filtered, air dried and then used directly for preparation of final products.

Yield: 20%; m.p.: 62-64 ℃; MS: *m/z* (rel. int.) = 138 (M^+, 68.3), 102 (44.4), 63 (100). Anal. Calcd. for $C_3H_8ClN_3O$: C, 26.19; H, 5.86; N, 30.55. Found: C, 25.96; H, 6.05; N, 30.65.

General procedure for the preparation of 2a-g and 3a-f. To a solution of the appropriate carbonyl starting material (1 mmol) in EtOH (10 ml) and 10 drops glacial acetic acid was added equimolar amount of **1**. The resulting mixture was stirred for 2 h then added to 50 mL ice-cold water. The resulting precipitate was filtered under vacuum, washed with water and finally crystallized from EtOH.

2a. 1-Benzylidene-4-(2-chloroethyl) semicarbazide. Yield: 53%; m.p.: 112-113 ℃; IR: υ = 3410, 3189 (NH), 3093 (CH, aromatic), 2957(CH, aliphatic), 1685 (C=O), 1605(C=N),1543 (C=C) cm^{-1}; MS: *m/z* (rel. int.) = 227 (M^++2, 2.0), 226(M^++1, 2.5),225 (M^+, 3.8), 188 (9.3), 147 (3.6), 119 (100), 91 (17). Anal. Calcd. for $C_{10}H_{12}ClN_3O$: C, 53.22; H, 5.36; N, 18.62. Found: C, 53.03; H, 5.66; N, 18.45.

2b. 1-(*p*-Methylbenzylidene)-4-(2-chloroethyl) semicarbazide. Yield: 79%; m.p.: 148-150 ℃; IR: υ = 3414, 3174 (NH), 3090 (CH, aromatic), 2944 (CH, aliphatic), 1674 (C=O), 1613(C=N), 1537 (C=C) cm^{-1}; MS: *m/z* (rel. int.) = 202(M^+-36.5, 13.8), 133 (87.9), 91 (64.9), 73 (100). Anal. Calcd. for $C_{11}H_{14}ClN_3O$: C, 55.12; H, 5.89; N, 17.53. Found: C, 55.24; H, 5.41; N, 17.3.

2c. 1-(*p*-Fluorobenzylidene)-4-(2-chloroethyl) semicarbazide. Yield: 80%; m.p.: 161-163 ℃; IR: υ = 3431, 3182 (NH), 3090 (CH, aromatic), 2953 (CH, aliphatic), 1685 (C=O), 1610(C=N), 1540 (C = C), 1225 (C-F) cm^{-1}; MS: *m/z* (rel. int.) = 245 (M^++2, 6.6), 244(M^++1, 8.1),243 (M^+, 19), 208 (0.7), 165 (3.0), 137 (100), 109 (9.3), 95 (29.05), 63 (35.7). Anal. Calcd. for $C_{10}H_{11}ClFN_3O$: C, 49.29; H, 4.55; N, 17.25. Found: C, 49.24; H, 4.62; N, 17.20.

2d. 1-(*p*-Chlorobenzylidene)-4-(2-chloroethyl) semicarbazide. Yield: 73%; m.p.: 175-177 ℃; IR: υ = 3408, 3184 (NH), 3091 (CH, aromatic), 2944 (CH, aliphatic), 1678 (C=O), 1607(C = N), 1532 (C = C) cm^{-1}; ^{1}H NMR (90 MHz, δ): 3.45-3.50 (m, 2H, CH_2), 3.70-3.80 (m, 2H, CH_2), 7.35 (t, 1H, $\underline{N\mathit{H}}CH_2$), 7.40-7.45 (d, 2H, ArH), 7.75-7.80 (d, 2H, ArH), 7.85 (s, 1H, CH = N), 10.60 (s, 1H, C = NN*H*) ppm; MS: *m/z* (rel. int.) = 259 (M^+, 6.6), 222 (5), 181 (2.7), 154 (61.3), 119 (25.6), 73 (100). Anal. Calcd. for $C_{10}H_{11}Cl_2N_3O$: C, 46.17; H, 4.26; N, 16.15. Found: C, 46.39; H, 4.35; N, 16.09.

2e. 1-(p-Methoxybenzylidene)-4-(2-chloroethyl) semicarbazide. Yield: 65%; m.p.: 167-168 ℃; IR: υ = 3401, 3181 (NH),3014 (CH, aromatic), 2948 (CH, aliphatic), 1694(C=O), 1605(C=N), 1534 (C=C) cm^{-1}; MS: *m/z* (rel. int.) = 255 (M^+, 39.5), 220(10.4), 219 (11.7), 150 (6.1), 165 (56.5), 149 (60.2), 133(81.6), 63(100.0). Anal. Calcd. for $C_{11}H_{14}ClN_3O_2$: C, 51.67; H, 5.52; N, 16.43. Found:

C, 51.81; H, 5.60; N, 16.33.

2f. 1-(p-Benzyloxybenzylidene)-4-(2-chloroethyl) semicarbazide. Yield: 60%; m.p.: 145-147 ℃; IR: υ = 3403, 3186 (NH), 3092 (CH, aromatic), 2959 (CH, aliphatic), 1687 (C=O), 1606(C=N), 1550 (C=C) cm^{-1}; ^{1}H NMR (200 MHz, δ): 3.42-3.48 (m, 2H, CH$_2$), 3.66-3.68 (m, 2H, CH$_2$), 5.14 (s, 2H, OCH$_2$), 7.02-7.05 (d, 2H, ArH), 7.18-7.22 (t, 1H, N*H*CH$_2$,exch.), 7.33-7.47 (m, 5H, ArH), 7.64-7.67 (d,2H,ArH),7.79(s,1H,CH=N);10.29(s,1H,NN*H*, exch.)ppm; Anal. Calcd. For $C_{17}H_{18}ClN_3O_2$: C, 61.54; H, 5.47; N, 12.66. Found: C, 61.77; H, 5.68; N, 12.18.

2g. 1-(p-Nitrobenzylidene)-4-(2-chloroethyl) semicarbazide. Yield: 75%; m.p.: 190-192 ℃; IR: υ = 3420, 3200 (NH), 3082 (CH, aromatic), 2940 (CH, aliphatic), 1682(C=O), 1598(C=N), 1575 (C=C), 1537,1335(NO$_2$) cm^{-1}; MS: *m/z* (rel. int.) = 273(M$^+$+2,6.0),272(M$^+$+1,3.8), 271 (M$^+$, 13.4), 270 (3.4), 235 (3.7), 166 (6.1), 165 (51.4), 63 (100.0). Anal. Calcd. for $C_{10}H_{11}ClN_4O_3$: C, 44.37; H, 4.10; N, 20.70. Found: C,44.56 ; H,4.22 ; N,20.60.

3a. 1-(1-Phenylethylidene)-4-(2-chloroethyl) semicarbazide. Yield: 37%; m.p.: 120-121 ℃; IR: υ = 3415, 3185 (NH), 3077 (CH, aromatic), 2939 (CH, aliphatic), 1677 (C=O), 1613 (C=N), 1533 (C=C) cm^{-1}; MS: *m/z* (rel. int.) = 240(M$^+$+1, 1.8), 239 (M$^+$, 15.3), 133 (62.23), 77 (100), 63 (64.0). Anal. Calcd. for $C_{11}H_{14}ClN_3O$: C, 55.12; H, 5.89; N, 17.53. Found: C, 55.02; H, 5.95; N, 17.36.

3b. 1-[1-(p-Methylphenyl)ethylidene]-4-(2-chloroethyl) semicarbazide. Yield: 55%; m.p.: 148-150 ℃; IR: υ = 3415, 3189 (NH), 3085 (CH, aromatic), 2946 (CH, aliphatic), 1671 (C=O), 1619 (C=N), 1530 (C=C) cm^{-1}; ^{1}H NMR (200 MHz, δ): 2.16 (s, 3H, CH$_3$C=N), 2,31(s, 3H, ArCH$_3$), 3,47-3.52 (m, 2H, CH$_2$), 3.65-3.69 (m, 2H, CH$_2$), 7.17-7.72 (d, 2H, ArH), 7.71-7.74 (d, 2H, ArH),8.10(br s, 1H, N*H*CH$_2$, exch), 9.45 (s, 1H, C=NNH, exch.)ppm; *m/z* (rel. int.) = 255(M$^+$+2, 4.5),254(M$^+$+1, 5.0), 253 (M$^+$, 11.7), 218 (2.5), 175 (5.6), 147 (100), 117 (29.2), 91 (61.2). Anal. Calcd. for $C_{12}H_{16}ClN_3O$: C, 56.80; H, 6.36; N, 16.56. Found: C, 56.42; H, 6.51; N, 16.65.

3c. 1-[1-(p-Bromophenyl)ethylidene]-4-(2-chloroethyl) semicarbazide. Yield: 40%; m.p.: 177-179 ℃; IR: υ = 3413, 3195 (NH), 3086 (CH, aromatic), 2957 (CH, aliphatic), 1676 (C=O), 1608 (C=N), 1523 (C=C) cm^{-1}; ^{1}H NMR (90 MHz, δ): 2.15 (s, 3H, CH$_3$C=N), 3.45-3.55 (m, 2H, CH$_2$), 3.65-3.75 (t, 2H, CH$_2$), 7.35 (t, 1H, N*H*CH$_2$), 7.55-7.60 (d, 2H, ArH), 7.80-7.85 (d, 2H, ArH), 9.65 (s, 1H, C=NNH)ppm; MS: *m/z* (rel. int.) = 320(M$^+$+1, 3.2), 319 (M$^+$, 9.1), 280 (11.3), 213 (49.7), 212 (49.0), 182 (24.6), 103 (66.7), 63 (100). Anal. Calcd. for $C_{11}H_{13}BrClN_3O$: C, 41.47; H, 4.11; N, 13.19. Found: C, 41.64; H, 4.02; N, 13.30.

3d. 1-[1-(p-Chlorophenyl)ethylidene]-4-(2-chloroethyl) semicarbazide. Yield: 32%; m.p.: 160-162 ℃; IR: υ = 3416, 3185 (NH), 3078 (CH, aromatic), 2940 (CH, aliphatic), 1676 (C=O), 1613 (C=N), 1533(C=C)cm^{-1}; MS: *m/z* (rel. int.) = 275 (M$^+$+2, 7.7),273 (M$^+$, 14.2), 238 (10.2), 195 (14.8), 167 (73.3), 137 (17.4), 103 (53.6), 63 (100). Anal. Calcd. for $C_{11}H_{13}Cl_2N_3O$: C, 48.19; H, 4.78; N, 15.33. Found: C, 48.06; H, 4.63; N, 15.51.

3e. 1-[1-(p-Methoxyphenyl)ethylidene]-4-(2-chloroethyl) semicarbazide. Yield: 59%; m.p.: 155-157 ℃; IR: υ = 3405, 3192 (NH), 3083 (CH, aromatic), 2947(CH, aliphatic), 1675 (C=O), 1608 (C=N), 1533(C=C) cm^{-1}; MS: *m/z* (rel. int.) = 269 (M$^+$, 36.9), 233 (10.5), 191 (12.7), 163(100), 134 (43.6), 63 (67.0). Anal. Calcd. for $C_{12}H_{16}ClN_3O_2$: C, 53.43; H, 5.98; N, 15.58. Found: C, 53.45; H, 5.94; N, 15.63.

3f. 1-[1-(p-Nitrophenyl)ethylidene]-4-(2-chloroethyl) semicarbazide. Yield: 87%; m.p.: 251-253 ℃; IR: υ = 3436, 3182 (NH), 3092 (CH, aromatic), 2972 (CH, aliphatic), 1679 (C=O), 1613 (C=N), 1575(C=C)cm^{-1}; MS: *m/z* (rel. int.) = 284 (M$^+$, 13.1), 249 (7.3), 179 (100), 149(4.2), 103 (14.1), 63 (32.88). Anal. Calcd. for $C_{11}H_{13}ClN_4O_3$: C, 46.41; H, 4.60; N, 19.68. Found: C, 46.41; H, 4.57; N, 19.79.

General procedure for the preparation of 4a-d

To a solution of the appropriate 5-substituted-1-H-indole-3-carboxaldehyde (1 mmol) in dioxane (10 ml), an equimolar amount of **1** and glacial acetic acid (10 drops) were added. The resulting mixture was stirred for 2 h and then added to 50 mL ice-cold water. The separated product was filtered under vacuum, washed with water, and finally crystallized from EtOH.

4a. 1-[(1H-indol-3-yl) methylidene]-4-(2-chloroethyl) semicarbazide. Yield: 54%; m.p.: 176-178 ℃; IR: υ = 3399-3210 (NH), 3056 (CH, aromatic), 2979, (CH, aliphatic), 1663 (C=O), 1621 (C=N), 1544(C=C) cm^{-1}; ^{1}H NMR (90 MHz, δ): 3.45-3.54 (m, 2H, CH$_2$), 3.65-3.75 (t, 2H, CH$_2$), 6.85 (t, 1H, N*H*CH$_2$), 7.10-8.20 (m, 5H, ArH + CH of fused pyrole), 8.05 (s, 1H, HC=N), 10.05 (s, 1H, C=NNH), 11.50 (s, 1H, NH of indole)ppm; MS: *m/z* (rel. int.) = 264 (M$^+$, 21.5), 228 (19.5), 185 (12.2), 158 (22.3),142(100.0), 129 (72.5), 116 (22.9), 63 (59.0). Anal. Calcd. for $C_{12}H_{13}ClN_4O$: C, 54.45; H, 4.95; N, 21.17. Found: C, 54.54; H, 5.36; N, 20.79.

4b. 1-[(5-Chloro-1H-indol-3-yl)methylidene]-4-(2-chloroethyl) semicarbazide. Yield: 50%; m.p.: 219-221 ℃; IR: υ = 3389-3173, (NH), 3091 (CH, aromatic), 2913 (CH, aliphatic), 1656 (C=O), 1610 (C=N), 1543(C=C) cm^{-1}; MS: *m/z* (rel. int.) = 300 (M$^+$ 2, 4.3), 298 (M$^+$, 5.9), 262 (28.5), 193 (14.3), 163 (100), 151 (12.1), 63 (42.8). Anal. Calcd. for $C_{12}H_{12}Cl_2N_4O$: C, 48.18; H, 4.04; N, 18.73. Found: C, 48.18; H, 4.37; N, 18.44.

4c.1-[(5-Methoxy-1H-indol-3-yl)methylidene]-4-(2-chloroethyl)semicarbaz ide. Yield: 71%; m.p.: 189-190 ℃; IR: υ = 3418-3230 (NH), 3081 (CH, aromatic), 2933, (CH, aliphatic), 1657 (C=O), 1619 (C=N), 1538 (C=C) cm^{-1}; MS: *m/z* (rel. int.) = 259 (M$^+$-36.5, 17.4), 172 (69.6),160 (23.2), 116(62.3), 87(100.0), 63(97.1). Anal. Calcd. for $C_{13}H_{15}ClN_4O_2$: C, 52.98; H, 5.13; N, 19.01. Found: C, 52.95; H, 5.54; N, 18.82.

4d.1-[(5-benzyloxy-1H-indol-3-yl)methylidene]-4-(chloroethyl)semicarbazi de. Yield: 37%; m.p.: 162-163 ℃; IR: υ = 3420-3170 (NH), 3094 (CH, aromatic), 2930 (CH, aliphatic), 1667 (C=O), 1621 (C=N),1577 (C=C, aromatic) cm^{-1}; ^{1}H NMR (200 MHz, δ): 3,52-3.56 (m, 2H, CH$_2$), 3.69-3.73 (t, 2H, CH$_2$), 5.16 (s, 2H, OCH$_2$), 6.78 (t, 1H, N*H*CH$_2$, exch.), 6.87-7.71 (m, 9H, ArH + CH of fused pyrole), 8.07 (s, 1H, HC=N), 10.05 (s, 1H, C=NNH, exch.), 11.34 (s, 1H, NH of indole, exch.)ppm; MS: *m/z* (rel. int.) = 334 (M$^+$-36.5, 30.1), 265 (19.4), 248 (11.7),146(28.1), 91 (100.0), 63 (17.9). Anal. Calcd. for $C_{19}H_{19}ClN_4O_2$: C, 61.54; H, 5.16; N, 15.11. Found: C, 61.20; H, 5.53; N, 14.87.

B) Cytotoxic activity evaluation. The Sulforhodamine B (SRB) assay of *Skehan* [15] was used to evaluate the cytotoxic activity of the semicabazides 2a-g,3a-f and 4a-d against two cell lines, U251 and Hepg2. These assays were performed at the Cancer Biology Department, Pharmacology Unit, National Cancer Institute, Cairo, Egypt. Cells were plated in 96-multiwell plates (10^4 cells/well) for 24 h before treatment with the compound to allow attachment of the cells to the wall of the plate. Using *DMSO* (0.02%) and saline solution as solvent system,[16,17] different concentrations of the compounds under test (10, 25, 50, 100 μg/mL) were added to the cell monolayer. Triplicate wells were prepared for each dose. Monolayer cells were incubated with the compound under test for 48 h at 37℃ and in atmosphere of 5% CO$_2$. After 48 hours, cells were fixed, washed and stained with Sulforhodamine B stain. Excess stain was washed with acetic acid and then after attached stain was recovered with Tris EDTA buffer. Color intensity was measured in an ELISA reader. IC$_{50}$ value was determined for each tumor cell line for the specified compound, calculated by an available computerized program, which was defined as the concentration of drug to produce a 50% reduction in the viability relative to the control and results were recorded in table 1.

Acknowledgments. The authors would like to thank the Cancer Biology Department, Pharmacology Unit, National Cancer Institute, Cairo, Egypt for performing cytotoxic activity assay.

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