RESEARCH COMMUNICATION

Retinoid Receptors in Gastric Cancer: Expression and Influence on Prognosis

Kong-Wang Hu¹², Fei-Hu Chen²*, Jin-Fang Ge², Li-Yu Cao³, Hao Li³

Abstract

**Background:** Gastric cancer is frequently lethal despite aggressive multimodal therapies, and new treatment approaches are therefore needed. Retinoids are potential candidate drugs: they prevent cell differentiation, proliferation and malignant transformation in gastric cancer cell lines. They interact with nuclear retinoid receptors (the retinoic acid receptors [RARs] and retinoid X receptors [RXRs]), which function as transcription factors, each with three subclasses, α, β and γ. At present, little is known about retinoid expression and influence on prognosis in gastric cancers. **Patients and Methods:** We retrospectively analyzed the expression of the subtypes RARα, RARβ, RARγ, RXRα, RXRβ, RXRγ by immunohistochemistry in 147 gastric cancers and 51 normal gastric epithelium tissues for whom clinical follow-up data were available and correlated the results with clinical characteristics. In addition, we quantified the expression of retinoid receptor mRNA using real-time PCR (RT-PCR) in another 6 gastric adenocarcinoma and 3 normal gastric tissues. From 2008 to 2010, 80 patients with gastric cancers were enrolled onto therapy with all-trans-retinoic acid (ATRA). **Results:** RARα, RARβ, RARγ and RXRγ positively correlated with each other (p < 0.001) and demonstrated significantly lower levels in the carcinoma tissue sections (p < 0.01), with lower RARβ, RARγ and RXRα expression significantly related to advanced stages (p < =0.01). Tumors with poor histopathologic grade had lower levels of RARα and RARβ in different histological types of gastric carcinoma (p < 0.01). Patients whose tumors exhibited low levels of RARα expression had significantly lower overall survival compared with patients who had higher expression levels of this receptor (p < 0.001, HR=0.42, 95.0% CI 0.24-0.73), and patients undergoing ATRA treatment had significantly longer median survival times (p = 0.007, HR=0.41, 95.0% CI 0.21-0.80). **Conclusions:** Retinoic acid receptors are frequently expressed in epithelial gastric cancer with a decreased tendency of expression and RARα may be an indicator of a positive prognosis. This study provides a molecular basis for the therapeutic use of retinoids against gastric cancer.

**Keywords:** Stomach neoplasms - prognostic factors - retinoic acid receptors - ATRA - therapy

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Introduction

The incidence of gastric carcinoma is declining, it remains the second leading cause of cancer-related mortality worldwide (Crew and Neugut, 2006) with five-year survival in France (32.6%), the USA (26%), China (30.5%), Iran (24%) and Japan (screening: 89.4%, no screening: 66.5%) (Msika et al., 2000; Cunningham et al., 2005; Kunisaki et al., 2006; Deng et al., 2010; Khedmat et al., 2011), by the time of diagnosis, most patients have advanced stages of disease (Deng et al., 2010). Its achievement of locoregional control for advanced disease remains very difficult, despite multimodal therapy, 54% of patients had locoregional recurrence (Gunderson and Sosin, 1982). Therefore, ongoing research focuses on the development of more potent therapies. Use of neoadjuvant and adjuvant treatment to further improve results continues to be investigated. A biological approach might lead to further individualized treatment options.

Retinoic acid has been recognised as a pivotal compound in cell differentiation, proliferation and malignant transformation (Shyu et al., 1995; Tanaka and De Luca, 2009). Retinoids are natural and synthetic derivatives of retinol (vitamin A). The naturally occuring retinoids, all-trans retinoic acid, 9-cis retinoic acid and 13-cis retinoic acid, are generated from diet-derived retinol. Retinoids are ligands of cellular receptors of retinoic acid, including retinoic acid receptors (RARs) and retinoid X receptors (RXRs) who are members of the steroid and thyroid hormone receptor superfamily (Evans, 1998; Sun and Lotan, 2002). Each subtype of both retinoid receptor classes (RARα, RARβ, RARγ and RXRα, RXRβ, RXRγ respectively) is encoded by separate genes. Multiple isoforms of receptor subtypes exist as a result of

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alternate splicing. The receptors act mainly as RAR–RXR heterodimers, bind to specific DNA sequences (retinoic acid response elements) and act as ligand-dependent transcription factors (Altucci and Gronemeyer, 2001). The RAR family is endogenously activated by ATRA and 9-cis-RA, whereas the RXR family is activated by 9-cis-RA only (Mangelsdorf et al., 1994).

Retinoids are essential in the maintenance of normal adult epithelial differentiation. Vitamin A-deficient experimental animals have long been known to develop squamous metaplasia and other precancerous lesions. These alterations were reversed by vitamin A repletion (Lippman et al., 1994; Sankaranarayanan and Mathew, 1996). Several subsequent studies demonstrated the effect of retinoids in the chemoprevention of certain malignant tumors (Lippman et al., 1994; Sankaranarayanan and Mathew, 1996). The growth inhibitory effect of retinoids has also been extensively studied in established gastric carcinoma cell lines (Shyu et al., 1995; Wu et al., 2000; Xu et al., 2006).

Retinoids strengthen the effect of cytotoxic drugs, such as docetaxel and cisplatin and of ionizing radiation in some cancer cell lines (Jozan and Lafon, 1996; Aebi et al., 1997; Jozan et al., 2002; Scribner Jr and Benbrook, 2002; Wang and Wieder, 2004). The therapeutic effects of retinoids differ from those of traditional cytotoxic agents. Thus, retinoids are potentially fascinating partners for combination therapies with cytotoxic drugs. Certain retinoids are in clinical use, such as all-trans retinoic acid in the treatment of acute promyelocytic leukemia (Sanz et al., 1998) and bexarotene in the therapy of cutaneous T-cell lymphoma (Farol and Hymes, 2004), but their clinical application for the therapy of solid tumors such as gastric cancer is still unknown.

Despite the knowledge of the biological effects of retinoids in gastric cancer, limited information is available on the expression of all isoforms of retinoid receptors in these tumors. Therefore, the objective of the present study was to systematically investigate the expression of RARs and RXRs in paraffin embedded gastric cancer tissues using immunohistochemistry, and to measure the mRNA expression of all RARs and RXRs subtypes in frozen tissue samples with real-time quantitative PCR to evaluated the relation of RARs/RXRs expression with clinicopathological features and also its effect on prognosis, and then, we assessed all-trans retinoic acid was tested for treating the patients with gastric cancer in combination with a cytotoxic agent in vivo.

Materials and Methods

Patients and Tissue samples

147 gastric cancer tissues and 51 distal normal tissues between January 2001 and April 2010 were included in the present study. The surgically resected tissues were fixed in 10% neutral formalin and embedded in paraffin. Haematoxylin and eosin (H&E)-stained tissue sections were screened for histopathologic confirmation based on the WHO Histological Classification (Hamilton and Aaltonen, 2000). All patients were classified according to the 7th edition AJCC/UICC TNM staging systems (Edge et al., 2010). Before processing for RARs/RXRs immunostaining, all available tissue blocks were reviewed for the presence of tumor by a pathologist (LY.C.). Frozen samples for the real-time PCR (RT–PCR) analysis from another 6 gastric adenocarcinoma tissues and 3 normal gastric mucin tissues were collected. Tumor samples were selected by the surgeon and by a pathologist (H.L.) to exclude macroscopically identifiable non-tumor tissue. The tissue was snap-frozen in liquid nitrogen in the operating theatre and stored at -70 °C until further processing.

Immunohistochemistry

For immunohistochemistry, paraffin-embedded tissue sections were cut (5 μm thickness) and mounted on poly-L-lysine-coated slides. The Avidin-Biotin-Peroxidase complex method was described by Hsu (Hsu et al., 1981). Briefly, the sections were dewaxed, hydrated and incubated in 0.5% (v/v) H₂O₂ in methanol for 20 min to block endogenous peroxidase activity. Slides were washed in Tris-buffered saline (TBS) and heated for 5 min at 100°C in 10 mM sodium citrate buffer (pH 6.0) for antigen retrieval. Slides were permitted to cool to 37 °C, followed by rinsing in TBS. Sections were then incubated with a 1:300 dilution of all antibodies overnight at 4 °C in a humidified chamber. anti-RARa (SC-551), anti-RARB (SC-552), anti-RARg (sc-7387), anti-RXRa (sc-553) and anti-RXRG (SC-555) were purchased from Santa Cruz Biotechnology, and anti-RXRB (LS-C38975) antibody from LifeSpan BioSciences. After extensive rinsing with TBS, sections were incubated with biotinylated anti-mouse antiserum and subsequently with horseradish peroxidase streptavidin conjugate. Sections were rinsed and color was developed using 3, 3-diaminobenzidine hydrochloride (DAB) as chromogen. Finally, sections were rinsed in distilled water, counterstained with Mayer’s hematoxylin and mounted for evaluation with DPX mountant. The primary antibody was omitted in the negative control. As positive controls, sections of human skin and liver (for all receptors) were incubated with the same antibody. The expression of all antigens defined as nuclear or cytoplasm staining was scored semiquantitatively described by Richter et al., (2002). The immunohistochemical staining was evaluated in 5 areas of the slide sections for correlation and confirmation of the tissue analysis. The results of staining with the percentage and intensity of positive cells for each section was scored 0 to 3 arbitrarily to reflect negative, light, moderate, and strong, respectively. Each slide was evaluated independently by two individuals (LY.C. and H.L.) who both were the Professor of Pathology. Any discrepancy in the scoring of slides was resolved jointly by both of them by discussion and a consensus observation was recorded after discussion.

cDNA synthesis and RT–PCR

Thirty milligrams of frozen tumor tissue was disrupted with a mortar and pestle with concurrent cooling with liquid nitrogen. Total RNA was extracted using the RNeasy Mini kit (Qiagen, Basel, Switzerland) according to the manufacturer’s instructions. cDNA was synthesized
from 1 mg total RNA in 25 ml reaction buffer using MMLV reverse transcriptase, recombinant RNasin (Promega, Wallisellen, Switzerland) and random primers p(dN)6 (Roche, Rotkreuz, Switzerland) after DNase digestion with DNase I (Roche, Rotkreuz, Switzerland). The cDNA products were used for RT–PCR in a reaction mixture (25 µl) containing 12.5 µl 2 x SYBR Green PCR Master Mix (Applied Biosystems, Foster City, CA, USA) and forward and reverse primer at 300 nM. The primers for RARa, RARb, RARg and RXRa, RXRb, RXRg were designed according to the NCBI reference sequences for the corresponding genes by Primer 5.0 (Table 1). 7S rRNA was used as reference target sequence (primers: 50-accacaggttgcctaagga and 50-cacgggagttttgacctgct). We used the ABI PRISM 9700 Sequence Detection System for RT–PCR. The following parameters were for the RT–PCR: initial denaturation (10min at 95 °C) followed by 45 amplification cycles (denaturation for 30 s at 95 °C, annealing for 30 s at 55 °C and elongation for 15 s at 72 °C). We excluded the formation of primer dimers by final melting curve analysis after RT–PCR (temperature slope 0.05 °C/s from 40 to 100 °C). All samples were measured as duplicates with a no-template control in each run. Calibration curves for each resulting plasmid were established using 10-fold serial dilutions in 50 mg/ml yeast RNA (Ambion, Huntingdon, UK). The concentration of 7S was used as a control for RNA content and for normalization of RNA content of each sample.

Table 1. Real Time PCR Primers Sequences for RARa, RARb, RARg and RXRa, RXRb, RXRg

<table>
<thead>
<tr>
<th>Gene</th>
<th>Reference of sequence no.</th>
<th>Sequence</th>
<th>Product size(bp)</th>
<th>TM</th>
<th>GC%</th>
</tr>
</thead>
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<tr>
<td>RARA</td>
<td>NM_000964</td>
<td>F: CTG CTC CCC CTC GAG ATG GAT</td>
<td>217</td>
<td>65.8</td>
<td>61.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>R: ATG CTT CTC AGC AGG TCA GTA ATC TTC A</td>
<td>64.5</td>
<td>44</td>
<td></td>
</tr>
<tr>
<td>RARB</td>
<td>NM_000965</td>
<td>F: CC TGC CTT TGG AAA TGG ATG</td>
<td>167</td>
<td>60.3</td>
<td>50</td>
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<td></td>
<td></td>
<td>R: GAG GCT TGC TGG GTC GTC TT</td>
<td>61.3</td>
<td>61.6</td>
<td></td>
</tr>
<tr>
<td>RARG</td>
<td>NM_000966</td>
<td>F: CAA GGT CAG CAA AGC ACA CCA TCA G</td>
<td>169</td>
<td>64.4</td>
<td>54.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>R: CCG CTT GGC AAA CTC CAC GAT</td>
<td>66.8</td>
<td>57.1</td>
<td></td>
</tr>
<tr>
<td>RXRA</td>
<td>NM_002957</td>
<td>F: CTG TGG GTA GTC GGC TGG TGG TGT</td>
<td>160</td>
<td>62.1</td>
<td>61.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>R: GAA ACC GCT CCG CTC TCT CTG</td>
<td>65.8</td>
<td>61.9</td>
<td></td>
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<tr>
<td>RXRB</td>
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<td>F: TTT TGT AGT GGG CGA AGA AGA GGA T</td>
<td>180</td>
<td>63.4</td>
<td>50</td>
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<tr>
<td></td>
<td></td>
<td>R: AAT GGG CTG AGT ATG TGC GGT GC</td>
<td>65.4</td>
<td>60</td>
<td></td>
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<tr>
<td>RXRG</td>
<td>NM_006917</td>
<td>F: CCT CTT TCT CCC ACC GCT CAG</td>
<td>183</td>
<td>63.6</td>
<td>61.9</td>
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<td></td>
<td></td>
<td>R: CTC GCA GGC ATC CCA GTT CC</td>
<td>65</td>
<td>65</td>
<td></td>
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</table>
Figure 1. Representative Example Demonstrating the Immunohistochemical Staining of Retinoic Acid Receptors (RARs) α, β, and γ in Gastric Adenocarcinoma Tissue. (A-D) RARα. (A) Normal gastric epithelium (NGE): nuclear staining, strongly positive (×100). (B) Well-differentiated adenocarcinoma (WDA): cytoplasm staining, strongly positive (×400). (C) Moderate-differentiated adenocarcinoma (MDA): cytoplasm staining, strongly positive (×200). (D) Poorly differentiated adenocarcinoma (PDA): cytoplasm staining, moderately positive (×100).

Figure 2. Representative Example Demonstrating the Immunohistochemical Staining of Retinoid X Receptors (RXRs) α, β, and γ in Gastric Adenocarcinoma Tissue. (A-D) RXRα. (A) Normal gastric epithelium (NGE): cytoplasm staining, moderately positive (×100). (B) Well-differentiated adenocarcinoma (WDA): nuclear and cytoplasm staining, moderately positive (×100). (C) Moderate-differentiated adenocarcinoma (MDA): cytoplasm staining, moderately positive (×200). (D) Poorly differentiated adenocarcinoma (PDA): nuclear staining, moderately positive (×100).

Figure 3. the mRNA Expression of RARs/RXR in Normal Gastric Epithelium and Carcinomas

Results

Immunohistochemical study

Nuclear or cytoplasmic staining was considered positive. Nuclear or cytoplasm expression of RARα, RARβ, RARγ, RXRa and RXRγ was present in carcinoma cells and normal gastric epithelium (Figure 1 and 2). Specific high immunoreactivity for RXRβ was not discernible, neither in a selection of gastric cancers or in normal gastric tissues that were supposed to express the antigen. Then, we found in RT–PCR study that less mRNA for RXRβ was detected in frozen gastric cancer tissue. The expressions of RARα, RARβ, RARγ, RXRa, RARβ and RXRγ versus the main clinical and pathological characteristics were summarized in Table 2.

RARα, RARβ, RARγ and RXRγ had a significantly lower score in the carcinoma tissue sections than normal gastric epithelium (p = 0.022, 0.002, 0.001, < 0.001 respectively). Lower RARβ, RARγ and RXRα expressions were significantly related to advanced TNM stages (P = 0.011, 0.010, 0.013 respectively). Tumors with poor histopathologic cell differentiation had lower levels of RARα and RARβ in different histological grades of gastric carcinoma (P < 0.01). There was no significant relation between RARα, RARβ, RARγ, RXRa, RXRβ and RXRγ expressions and other clinical or pathological features. There was no difference of nuclear or cytoplasmic location among cell differentiation, Stage of TNM and Histology (data not shown). The expressions among RARα, RARβ, RARγ, RXRa and RXRγ were significantly positively correlated (P < 0.001, Table 3).

RNA expression study

The results of mRNA quantitation of the major classes of retinoid receptors are summarized in (Figure3). All the mRNA expressions of the receptors of RARα, RARβ, RARγ, RXRa, RXRβ and RXRγ were expressed in normal gastric epithelium and carcinomas, and
Table 2. Expression of Retinoid Receptor by Immunohistochemistry

<table>
<thead>
<tr>
<th>Age, year</th>
<th>Gender</th>
<th>Female</th>
<th>Male</th>
<th>cell differentiation</th>
<th>Stage of TNM</th>
<th>Histology</th>
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<tr>
<td>&lt;50</td>
<td>14(41.2%)</td>
<td>37(50.0%)</td>
<td>18(46.2%)</td>
<td>5(15.6%)</td>
<td>7(22.6%)</td>
<td>15(41.7%)</td>
</tr>
<tr>
<td>51–65</td>
<td>9(26.5%)</td>
<td>18(24.3%)</td>
<td>9(23.1%)</td>
<td>25(22.5%)</td>
<td>11(33.3%)</td>
<td>9(28.6%)</td>
</tr>
<tr>
<td>&gt;65</td>
<td>8(23.5%)</td>
<td>14(18.9%)</td>
<td>8(20.5%)</td>
<td>24(21.6%)</td>
<td>6(16.7%)</td>
<td>8(25.8%)</td>
</tr>
</tbody>
</table>

| RXRγ | 3 (8.8%) | 5 (14.7%) | 1 (2.8%) | 2 (5.6%) | 1 (2.8%) | 3 (8.8%) | 2 (5.6%) | 1 (2.8%) | 2 (5.6%) | 1 (2.8%) | 3 (8.8%) | 2 (5.6%) | 1 (2.8%) | 2 (5.6%) |
| RXRα | 1 (2.8%) | 3 (8.8%) | 2 (5.6%) | 1 (2.8%) | 1 (2.8%) | 3 (8.8%) | 2 (5.6%) | 1 (2.8%) | 1 (2.8%) | 3 (8.8%) | 2 (5.6%) | 1 (2.8%) | 3 (8.8%) | 2 (5.6%) |

P* 0.98 0.418 0.002 0.226 0.002 0.002

| RXRβ | 2 (5.6%) | 5 (14.7%) | 1 (2.8%) | 2 (5.6%) | 1 (2.8%) | 3 (8.8%) | 2 (5.6%) | 1 (2.8%) | 2 (5.6%) | 1 (2.8%) | 3 (8.8%) | 2 (5.6%) | 1 (2.8%) | 2 (5.6%) |

P* 0.004 0.248 0.002 0.002 0.002 0.002

| RXRγ | 1 (2.8%) | 3 (8.8%) | 2 (5.6%) | 1 (2.8%) | 1 (2.8%) | 3 (8.8%) | 2 (5.6%) | 1 (2.8%) | 1 (2.8%) | 3 (8.8%) | 2 (5.6%) | 1 (2.8%) | 3 (8.8%) | 2 (5.6%) |

P* 0.001 0.028 0.001 0.001 0.001 0.001

Table 3. The Correlated Correlation among RARs and RXRs

<table>
<thead>
<tr>
<th>RARα</th>
<th>RARβ</th>
<th>RARγ</th>
<th>RXRα</th>
<th>RXRβ</th>
<th>RXRγ</th>
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<tr>
<td>RARα correlation coefficient</td>
<td>1.000</td>
<td>0.506</td>
<td>0.533</td>
<td>0.540</td>
<td>0.394</td>
</tr>
<tr>
<td>P</td>
<td>0.000</td>
<td>0.000</td>
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<table>
<thead>
<tr>
<th>RARβ</th>
<th>RARγ</th>
<th>RXRα</th>
<th>RXRβ</th>
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<tr>
<td>RARβ correlation coefficient</td>
<td>1.000</td>
<td>0.458</td>
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<td>0.578</td>
</tr>
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<td>P</td>
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<th>RARγ</th>
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<table>
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<td>RXRα correlation coefficient</td>
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<td>0.333</td>
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<td>P</td>
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<tr>
<th>RXRγ</th>
</tr>
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<tbody>
<tr>
<td>RXRγ correlation coefficient</td>
</tr>
</tbody>
</table>

Spearman rank correlation; RAR, retinoic acid receptor; RXR, retinoid X receptor; negative; 1, light positive; 2, moderate positive; 3, strong positive
RARβ, RARγ, RXRa, RXRβ, RXRγ, cell differentiation, tumor site, Borrmann style, tumor size, age and gender were independent and key predictors of survival by the method of Forward: LR (p<0.001), then overall survival (OS) was calculated using Kaplan–Meier estimator, the positive expression of RARa indicated a lower risk of death from gastric cancer (p<0.001, HR = 0.42, 95.0% CI for HR 0.24-0.73). Patients with RARa positive cancers had median survival time of 8.88 years (95.0% CI 5.85-11.91), whereas with RARa negative cancers the median survival time was 2.11 years (95.0% CI 1.31-2.91) (Figure 4).

Last, we treated the 80 patients in de novo gastric cancer with or without ATRA; overall survival was the primary end points of this study. Patients with ATRA treatment had median survival time of 8.88 years (95.0% CI 5.85-11.91), whereas without ATRA treatment the median survival time was 2.11 years (95.0% CI 1.31-2.91) (Figure 4).

Discussion

Despite substantial advancement of the surgical and medical therapy, gastric cancer continues to be a highly lethal disease. Even with state-of-the-art surgery and modern chemotherapy, the probability of five-year survival in the USA, Europe, and China generally is only 20–25% (Parkin, 2001).

The physiological functions of retinoids include the control of proliferation, apoptosis and differentiation in normal cells during growth and development by various mechanisms (Altucci and Gronemeyer, 2001; Huang et al., 2002; Mehta, 2003; Yoshida et al., 2003), interference with cell cycle control (Chao et al., 1997) and cross-talk with other signaling molecules such as AP1 (Wu et al., 2002) and mitogen-activated kinase signal pathways (Huang et al., 2002; Crowe et al., 2003). The expression of RARβ is induced by liganded RARα and is lost as an early event in the carcinogenesis of various tumors (Soprano et al., 2004). Most of the results from experimental animal studies indicate that retinoids are effective in preventing or suppressing cancers. Most biological effects of retinoids are mediated through retinoid receptors; previous work has established that retinoid receptors are expressed in a variety of gastric cancer cell lines (Shyu et al., 1995; Liu et al., 1998; Jiang et al., 1999; Liu et al., 2001; Lin et al., 2004; Ye et al., 2004; Karam et al., 2005).

However, the expression of retinoid receptors has hardly been investigated in clinical gastric cancer tissues. In the present study, the population in this study involved all patients treated at our research institution between 2001 and 2010 for whom tissues blocks were available, we observed that the retinoid receptors RARα, RARβ, RARγ, RXRa and RXRγ were present in a majority of gastric cancer tissues, but there were significantly lower expression levels of RARα, RARβ, RARγ and RXRγ than in normal gastric epithelium, especially lower expressions of RARβ, RARγ and RXRα in advanced-stage tumors and those of RARα and RARβ with poor differentiation. High expression of RXRβ did not exist not only in gastric cancers but also in normal gastric mucosal tissues. These results could be concluded from proteinaceous levels by immunohistochemistry and genetic transcriptive levels by RT-PCR in the present study. According to previous study (Hayashi et al., 2001; Kim et al., 2004; Wu et al., 2004; Koike et al., 2005; Shutoh et al., 2005; Ben Ayed-Guerfali et al., 2011), the lower expressions of retinoid receptors RARα, RARβ, RARγ, RXRa and RXRγ were synthetically caused by DNA methylation and genetic acetylation of genetic transcriptive levels and the ubiquitin/proteasome pathway and the sumoylation pathway of proteinaceous levels. The results also revealed the expressions of RARα and RARβ maybe act as the markers of the cell differentiation in different histological types of gastric carcinoma, the poorer on histopathologic grade, the lower on expressions of RARα and RARβ.

We further detected that the low expression of RARα independently predicts an unfavorable prognosis in addition to established prognostic factors such as AJCC stage in this study. It is thus not surprising that the high
expression of RARa was a positive prognostic factor of survival. Converse observations were made in oral squamous cell carcinoma, where RARa was an independent indicator of a poor prognosis (Chakravarti et al., 2003). RARa was correlated with unfavorable prognostic factors such as high grade and high proliferation rate in prostate (Gyftopoulos et al., 2000) and breast (van der Leede et al., 1996) cancer.

All-trans retinoic acid was one of the first examples of ‘targeted’ therapy: it induces remissions in a majority of patients with promyelocytic leukemia by differentiation therapy (Sachs, 1978a; 1978b; Petrie et al., 2009). Moreover, retinoids prevent the development of solid tumors and are also effective in the therapy of certain solid tumors (Reynolds, 2000; Lippman et al., 2001; Abu et al., 2005; Coelho et al., 2005; Pasquali et al., 2006; Zanardi et al., 2006; Khuri et al., 1997; Riecken and Rosewicz, 1999). This interesting biological activity profile of retinoids has prompted investigators to study them in the chemoprevention of epithelial cancers and in the treatment of advanced cancers (Lippman et al., 1994; Sankaranarayanan and Mathew, 1996). Although the therapeutic response of retinoids against advanced cancers is disappointing, retinoids interact in vitro with conventional cytotoxic drugs such as cisplatin and the taxanes paclitaxel and docetaxel to lower the threshold of apoptosis (Jozan and Lafon, 1996; Aebi et al., 1997; Wang et al., 2000; Nehme et al., 2001; Jozan et al., 2002; Wang and Wieder, 2004; Garattini et al., 2007). This study had investigated that ATRA could significantly prolong OS of the patients with gastric cancer combined conventional chemotherapy with a substantially better benefit to toxicity ratio and the expression of RARa was correlated with the responsiveness to ATRA. It was conceivable that a more selective use of retinoids exclusively in tumors that expressed RARα may be achieved more in combination with conventional chemotherapeutic on the patients with gastric cancer. Retinoids could induce mild, dose-related anemia and dose-related increases in serum alkaline phosphatase, cholesterol, triglycerides, and calcium levels, and increased platelet counts (Horn et al., 2007). The clinical side-effects of retinoids in present study do not overlap with the typical toxicity of cytotoxic chemotherapeutic agents. Thus, clinical evidence made retinoids attractive investigational agents for the combination with conventional cytotoxic chemotherapy in gastric cancer.

In the present study, the expression among RARα, RARβ, RARγ, RXRa and RXRγ was significantly positively correlated. The presence of RXRs, although not of independent prognostic value in this study, may also be important: RXRs are obligatory dimerization partners for other members of the steroid receptor superfamily such as other retinoid receptor subtypes, the thyroid hormone receptor, the peroxisome proliferator-activated receptor gamma (PPARg), the orphan receptor and the vitamin D receptor.

Although the present investigation is limited by the small number of samples analyzed, it reveals that certain retinoid receptors are present in human gastric cancer. RARα may be associated with a positive prognosis independently of established prognosticators such as AJCC stage, and the patients with gastric cancer treated with ATRA combined with conventional cytotoxic chemotherapy could prolonged the OS significantly. This finding will have to be verified in a larger independent set of tumor samples. The present study provides the molecular basis for clinical trials to evaluate the efficacy of retinoids in gastric cancer; this prospect is promising in view of preclinical data that show a synergic interaction with fluorouracil, epirubicin, cisplatin drugs. Retinoids are potential candidates for new treatment strategies for gastric cancer.

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