

Molecular dysexpression in gastric cancer revealed by integrated analysis of transcriptome data

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Abstract. Gastric cancer (GC) is often diagnosed in the advanced stages and is associated with a poor prognosis. Obtaining an in depth understanding of the molecular mechanisms of GC has lagged behind compared with other cancers. This study aimed to identify candidate biomarkers for GC. An integrated analysis of microarray datasets was performed to identify differentially expressed genes (DEGs) between GC and normal tissues. Gene ontology and Kyoto Encyclopedia of Genes and Genomes (KEGG) enrichment analyses were then performed to identify the functions of the DEGs. Furthermore, a protein-protein interaction (PPI) network of the DEGs was constructed. The expression levels of the DEGs were validated in human GC tissues using reverse transcription-quantitative polymerase chain reaction (RT-qPCR). A set of 689 DEGs were identified in GC tissues, as compared with normal tissues, including 202 upregulated DEGs and 487 downregulated DEGs. The KEGG pathway analysis suggested that various pathways may play important roles in the pathology of GC, including pathways related to protein digestion and absorption, extracellular matrix-receptor interaction, and the metabolism of xenobiotics by cytochrome P450. The PPI network analysis indicated that the significant hub proteins consisted of SPPI, TOP2A and ARPC1B. RT-qPCR validation indicated that the expression levels of the top 10 most significantly dysexpressed genes were consistent with the illustration of the integrated analysis. The present study yielded a reference list of reliable

DEGs, which represents a robust pool of candidates for further evaluation of GC pathogenesis and treatment.

Introduction

Gastric cancer (GC) is one of the most prevalent cancers and the second most common cause of cancer-associated mortality worldwide (1). Almost one million people are diagnosed with GC each year. Despite decades of a steady decline in the incidence of GC, the GC fatality rate remains paradoxically high in most countries, particularly in those of East Asia (2). GC is a heterogeneous disease with numerous etiologies and potential pathways of carcinogenesis (3,4), resulting in a variation in the incidence rates of GC among different geographies, ethnicities and genders (5). One of the main etiological risk factors for GC is *Helicobacter pylori* infection, although only a small proportion of individuals infected with *H. pylori* develop GC (6,7).

Traditional methods for the treatment of GC include surgery, chemotherapy, radiation therapy and combination therapy, which is also known as multimodality therapy. However, GC is often asymptomatic during its early stage, which results in the advanced stage being generally refractory to those therapies (8). Even following radical gastrectomy, many patients experience disease recurrence and succumb to the disease within a few months to years; the 5-year survival rate of GC is $\leq 2/3$ (9,10). Therefore, an early and effective detection method that improves the chance of treating GC is imperative.

Microarrays are good tools for investigating the pathogenesis of various diseases (11-14). Compared with traditional methods, next-generation sequencing-based microarrays have the advantages of being unbiased, as they are not limited to previously known or annotated transcripts, and allowing more accurate quantification of genes with very low or high expression levels (15). In addition, transcriptome data detects other types of transcriptional signals, including alternative splicing, transcriptional starts/stops, gene fusions and expressed alleles (16). Studies based on microarrays have provided significant insights into the molecular basis of GC and novel therapeutic targets. However, microarrays have predominantly been used to characterize the genomic alterations of GC patients, while the validation of potential target genes for GC

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has been rare (10,17,18), restricting the application of microarrays to clinical practice.

The present study employed an integrated analysis of microarray data from the Gene Expression Omnibus (GEO) to identify the differentially expressed genes (DEGs) between GC and normal control (NC) tissues, which were then used to construct a protein-protein interaction (PPI) network. Furthermore, the significantly enriched functions of these genes were screened and analyzed to discover the biological processes and signaling pathways associated with GC. Finally, reverse transcription-quantitative polymerase chain reaction (RT-qPCR) of clinical samples was performed to validate the integrated analysis approach. This study may improve the methods used to elucidate the dysexpression of various genes in GC and be of some value for the future diagnosis of GC in the clinic.

Materials and methods

Microarray data and data preprocessing. Eligible GC gene expression datasets were identified by searching the GEO database (<https://www.ncbi.nlm.nih.gov/geo/>). Data were included if they met the following criteria: i) The expression profile of whole genome sequencing; ii) data from the tissues of GC patients in the clinic; and iii) raw or standardized data. Raw data were normalized using the Z-score transformation method (19) to make data from different platforms comparable. Matrix Laboratory software (version 2013a; MathWorks, Natick, MA, USA) was used to identify differentially expressed probe sets between tumor and adjacent tissues. A gene-specific *t*-test was performed, after which P-values and the effect size of individual microarray studies were calculated. The genes with a false discovery rate of ≤ 0.05 were selected as the significantly DEGs. DEGs between tumor and adjacent tissues were subsequently determined. Heat map analysis was conducted using the 'heatmap.2' function of the R/Bioconductor package 'gplots' (20).

Functional enrichment analysis of DEGs. To determine the biological functions of DEGs, Gene Ontology (GO) enrichment analysis of biological processes, molecular functions and cellular components was performed. The online software GeneCodis3 (<http://genecodis.cnb.csic.es/analysis>) was used to perform this analysis (21). In addition, pathway enrichment was also performed based on the Kyoto Encyclopedia of Genes and Genomes (KEGG) database (<http://www.genome.jp/kegg/>).

PPI network construction. A PPI network of the significantly dysexpressed genes was constructed according to data from the Biological General Repository for Interaction Datasets (<http://thebiogrid.org/>). Among the candidate genes, the distribution characteristics of the top 20 most significantly upregulated and downregulated DEGs were visualized using Cytoscape (22).

Collection of clinical specimens. A total of 10 patients, including 8 males and 2 females, were enrolled in the present study, among which 5 had been diagnosed with GC. The average age of the patients was 54 years (age range, 38-79 years). Frozen tissue sections were generated and examined independently

by senior pathologists. Parts of each tumor tissues were frozen immediately following the operation and stored at -135°C for RNA extraction. This study was approved by the Ethics Committee of The First Affiliated Hospital of PLA General Hospital (Beijing, China).

RNA preparation and RT-qPCR. Total RNA of each sample was extracted using the RNAeasy Mini kit (Qiagen, Inc., Valencia, CA, USA), according to the manufacturer's protocol. According to previous studies (23-27), 10 DEGs were retrieved from the top 20 upregulated and downregulated genes. Primers for the 10 target genes were designed using PrimerPlex 2.61 (Premier Biosoft International, Palo Alto, CA, USA) and are shown in Table I. cDNA templates were synthesized from 1-5 μg RNA using Superscript Reverse Transcriptase II (Thermo Fisher Scientific, Inc., Waltham, MA, USA). qPCR was performed on the ABI 7500 Real-Time PCR System (Applied Biosystems; Thermo Fisher Scientific, Inc.) with SYBR dye (Thermo Fisher Scientific, Inc.). The final reaction mixture of 12.5 μl consisted of 6.25 μl Power SYBR Green PCR Master Mix, 50 ng diluted cDNA and 1 μM of each primer. Reactions were conducted in triplicate under the following conditions: 50°C for 2 min, 95°C for 10 min, and 40 cycles of 95°C for 15 sec and 60°C for 1 min. Melting curves (60 to 95°C) were derived for every reaction to insure a single product. Relative gene expression was evaluated using Data Assist Software, version 3.0 (Thermo Fisher Scientific, Inc.), with the human actin gene as a reference. The expression levels of each gene were determined using the $2^{-\Delta\Delta\text{Cq}}$ method (28).

Statistical analysis. Data are expressed as the mean \pm standard deviation. Comparisons of the expression levels of different genes were conducted using Student's *t*-test with a significance level of 0.05. Statistical analyses were conducted using SPSS version 16.0 (SPSS, Inc., Chicago, IL, USA).

Results

DEGs in the integrated analysis of microarray datasets. Following the electronic database search, six microarray studies were obtained according to the inclusion criteria. The characteristics of the individual studies that were included in the integrated analysis are displayed in Table II. There were 53 GC patients and 259 NC patients. The integrated analysis identified a set of 689 DEGs in the GC tissues, as compared with the normal tissues, including 202 upregulated and 487 downregulated DEGs. In addition, the hierarchical clustering analysis indicated that the DEGs in GC were distinguished from those in normal tissues (Fig. 1).

Functional enrichment analysis. GO provides a common descriptive framework and functional annotation and classification system for analyzing the gene set data. The 689 DEGs were involved in 86 signaling pathways, including the digestion and absorption of proteins, interactions between extracellular matrix (ECM) receptors, the p53 signaling pathway, the metabolism of propionate, the absorption of minerals, etc. The results of the KEGG enrichment analysis revealed that the first three most enriched pathways included protein digestion

Table I. Primer sequences for the target genes.

Gene	Sequence (5' to 3')	Product size (bp)
<i>SULF1</i>	F: GTAAGAAGGAAGAATCCAGCAAGAA R: AGGTCACCTGGGTCTTTACACTT	187
<i>SPP1</i>	F: ATAAGCGGAAAGCCAATGATGAGAG R: TTTGGGGTCTACAACCAGCATATCT	134
<i>THBS2</i>	F: GAACATTGGCTGGAAGGACTACAC R: TCATAGATAGGTCTGAGTCTGCCA	126
<i>TOP2A</i>	F: ATCATTGAAAATAAGCCTAAGAAAG R: AGAAGATAGTTGAAGGTTGGTCC	197
<i>HOXC6</i>	F: GGACATAACACACAGACCTCAATCG R: GACCCCACTGTGCGAATTCAT	129
<i>GIF</i>	F: ATGGCATCATTGGAGACATCTACAG R: TTCTTGACAGTTCCATTCCTTTTATG	94
<i>KCNE2</i>	F: AGAGACGGGAACACTCCAATGACC R: ACTTTTCCTGCCAGTCCTCTACAATG	64
<i>SST</i>	F: AACCCAACCAGACGGAGAATGAT R: GCCGGGTTTGAGTTAGCAGATCTC	109
<i>GKNI</i>	F: AGGAAGTCATGCCCTCCATTCAATC R: GTTTTTTCCGAACCTTGCTCAGGTCA	149
<i>LIPF</i>	F: GAACTTTAACACGAGTCGCTTGGAT R: ATGGCTGTCACATTGTAGTAGGGAG	189
Actin	F: ACTTAGTTGCGTTACACCCTT R: GTCACCTTCACCGTTCCA	156

F, forward; R, reverse.

Table II. Information of the six transcriptome profiles.

GEO ID	Samples (cancer/normal)	Platform	Country	Year
GSE51575	26/26	GPL13607 Agilent-028004 SurePrint G3 Human GE 8x60K Microarray (Feature Number version)	Korea	2014
GSE29272	134/134	GPL96 [HG-U133A] Affymetrix Human Genome U133A Array	USA	2013
GSE37023-GPL96	112/39	GPL96 [HG-U133A] Affymetrix Human Genome U133A Array	Singapore	2012
GSE37023-GPL97	29/36	GPL97 [HG-U133B] Affymetrix Human Genome U133B Array	Singapore	2012
GSE33651	40/12	GPL2895 GE Healthcare/Amersham Biosciences CodeLink Human Whole Genome Bioarray	Korea	2011
GSE38932	12/12	GPL5936 HEEBO Human oligo array	Argentina	2012

GEO, Gene Expression Omnibus; HEEBO, human exonic evidence-based oligonucleotide.

and absorption, ECM-receptor interaction and the metabolism of xenobiotics by cytochrome P450 (Tables III and IV). The detailed information on the 20 most significantly upregulated and downregulated genes is shown in Table V.

PPI network construction. A PPI network of the top 10 upregulated and downregulated DEGs is shown in Fig. 2. The network consisted of 243 edges and 251 nodes. Generally, nodes with a high degree, which measures how many neighbors a node is directly connected to, are defined as hub proteins (29,30).

Three nodes, including SPP1, TOP2A and ARPC1B, showed the highest degrees.

RT-qPCR validation. Five genes were randomly retrieved from the 10 upregulated and downregulated genes, respectively. It was shown that the expression patterns of the selected genes in GC and normal tissues in the RT-qPCR analysis were similar to those in the integrated analysis (Fig. 3; Table V), and that the difference between the GC patients and control samples were significantly different ($P < 0.01$). The expression of SULF1,

Table III. Partial results of GO analysis.

GO term	GO name	No. of genes	P-value
Biological processes		22	7.04E-20
GO:0007586	Digestion	30	1.87E-10
GO:0051301	Cell division	30	4.74E-10
GO:0042493	Response to drug	41	5.44E-10
GO:0007155	Cell adhesion	20	1.68E-09
GO:0006805	Xenobiotic metabolic process	29	2.79E-08
GO:0008285	Negative regulation of cell proliferation	58	1.05E-07
GO:0007165	Signal transduction	31	3.71E-07
GO:0007049	Cell cycle	24	1.22E-06
GO:0005975	Carbohydrate metabolic process	12	1.31E-06
GO:0043434	Response to peptide hormone stimulus	25	1.33E-06
GO:0008152	Metabolic process	6	2.12E-06
GO:0006600	Creatine metabolic process	24	2.35E-06
GO:0000278	Mitotic cell cycle	10	2.41E-06
GO:0010033	Response to organic substance	13	3.53E-06
Molecular functions			
GO:0005515	Protein binding	192	4.51E-23
GO:0042803	Protein homodimerization activity	42	6.63E-12
GO:0016491	Oxidoreductase activity	38	1.15E-11
GO:0005509	Calcium ion binding	47	1.67E-11
GO:0042802	Identical protein binding	28	2.71E-09
GO:0005201	Extracellular matrix structural constituent	14	7.05E-09
GO:0008201	Heparin binding	18	7.53E-09
GO:0008009	Chemokine activity	10	2.40E-06
GO:0003824	Catalytic activity	26	3.55E-06
GO:0016787	Hydrolase activity	46	5.63E-06
GO:0000166	Nucleotide binding	79	6.03E-06
GO:0050840	Extracellular matrix binding	6	4.04E-05
GO:0008233	Peptidase activity	28	5.63E-05
GO:0019901	Protein kinase binding	18	8.70E-05
GO:0005198	Structural molecule activity	17	0.000169
Cellular components			
GO:0005576	Extracellular region	163	1.54E-55
GO:0005615	Extracellular space	93	6.61E-42
GO:0005737	Cytoplasm	242	3.60E-36
GO:0005886	Plasma membrane	151	2.66E-17
GO:0005829	Cytosol	105	1.08E-15
GO:0031012	Extracellular matrix	25	1.18E-14
GO:0048471	Perinuclear region of cytoplasm	36	1.27E-11
GO:0005887	Integral to plasma membrane	56	4.70E-10
GO:0016020	Membrane	141	1.29E-09
GO:0005634	Nucleus	173	4.31E-09
GO:0005581	Collagen	15	1.35E-08
GO:0005604	Basement membrane	13	3.41E-08
GO:0005578	Proteinaceous extracellular matrix	21	4.36E-08
GO:0005625	Soluble fraction	29	4.45E-08
GO:0009986	Cell surface	24	2.10E-07

GO, gene ontology.

SPP1, THBS2, TOP2A and HOXC6 was upregulated in GC tissues compared with normal tissues, while the expression of

GIF, KCNE2, SST, GKN1 and LIPF was downregulated in GC tissues compared with normal tissues.

Table IV. Partial results of the KEGG analysis.

KEGG ID	KEGG term	No. of genes	P-value
hsa04974	Protein digestion and absorption	19	1.77E-13
hsa04512	ECM-receptor interaction	16	9.65E-10
hsa00980	Metabolism of xenobiotics by cytochrome P450	13	5.40E-08
hsa05146	Amoebiasis	15	7.61E-08
hsa04971	Gastric acid secretion	13	8.50E-08
hsa04510	Focal adhesion	20	1.11E-07
hsa00071	Fatty acid metabolism	10	1.70E-07
hsa00982	Drug metabolism-cytochrome P450	12	3.32E-07
hsa04110	Cell cycle	15	5.78E-07
hsa00010	Glycolysis/gluconeogenesis	11	7.37E-07
hsa04978	Mineral absorption	10	1.03E-06
hsa04115	p53 signaling pathway	11	1.42E-06
hsa00640	Propanoate metabolism	8	2.52E-06
hsa00330	Arginine and proline metabolism	9	1.60E-05
hsa00591	Linoleic acid metabolism	7	1.71E-05

KEGG, kyoto encyclopedia of genes and genomes.

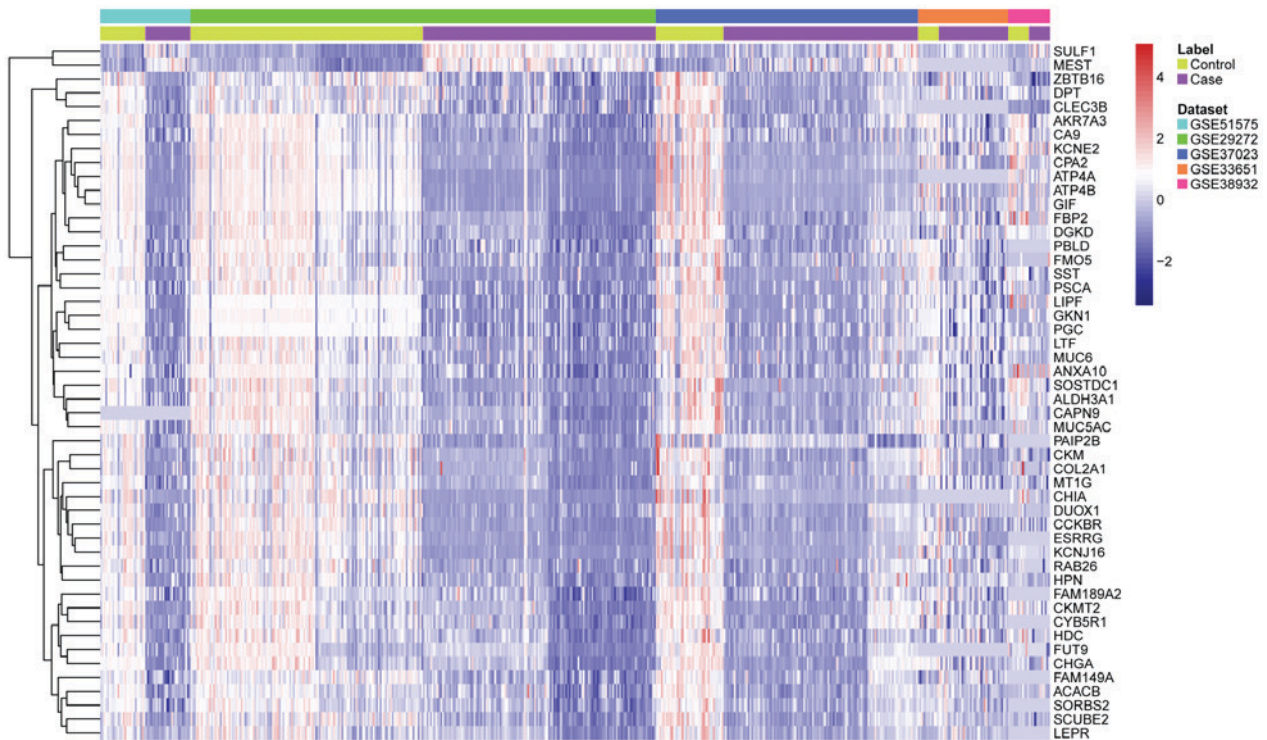


Figure 1. Heatmap visualization of the patterns of change for differentially expressed genes among samples from different datasets.

Discussion

Microarrays are powerful tools for revealing the pathogenesis of human cancer and identify potential therapeutic targets (12). Microarray-based technology has been used in several studies to detect candidate genes involved in the occurrence of GC (31-34). In the present study, an integrated analysis of six transcriptome datasets was conducted and 689 DEGs were

identified based on 612 samples, including 202 upregulated genes and 487 downregulated genes. The results of GO and KEGG analyses showed that the most enriched pathways included protein digestion and absorption, ECM-receptor interaction, and the metabolism of xenobiotics by cytochrome P450. The results were consistent with previous research (35,36), which identified DEGs with biological functions that were mainly involved in cell adhesion and ECM interactions.

Table V. Top ten significantly upregulated and downregulated DEGs.

DEG	Function	Fold-change	P-value
Upregulated			
<i>SULF1</i>	Exhibits arylsulfatase activity and highly specific endoglucosamine-6-sulfatase activity; diminishes heparan sulfate proteoglycan sulfation; inhibits signaling by heparin-dependent growth factors; diminishes proliferation; and facilitates apoptosis in response to exogenous stimulation	1.9208	6.89E-54
<i>MEST</i>	N/A	1.7879	2.94E-50
<i>SPPI</i>	Probably important to cell-matrix interaction; acts as a cytokine involved in enhancing the production of interferon- γ and IL-12 and reducing the production of IL-10; and is essential in the pathway that leads to type I immunity	2.5703	1.79E-47
<i>THBS2</i>	Mediates cell-to-cell and cell-to-matrix interactions. Ligand for cluster of differentiation 36, mediating angiogenic properties	2.0385	9.72E-44
<i>TOP2A</i>	Controls topological states of DNA by transient breakage and subsequent rejoining of DNA strands.	1.9398	4.07E-42
<i>HOXC6</i>	Provides cells with specific positional identities on the anterior-posterior axis	1.7265	3.34E-41
<i>HOXC10</i>	Provides cells with specific positional identities on the anterior-posterior axis	1.8234	4.42E-38
<i>ARPC1B</i>	Involved in regulating actin polymerization and, together with an activating nucleation-promoting factor, mediates the formation of branched actin networks	1.4555	2.10E-35
<i>KIF4A</i>	Translocates PRC1 to the plus ends of interdigitating spindle microtubules during the metaphase to anaphase transition; may play a role in mitotic chromosomal positioning and bipolar spindle stabilization	1.4195	2.38E-35
<i>OLFM12B</i>	N/A	1.6155	7.38E-35
Downregulated			
<i>GIF</i>	Promotes absorption of the essential vitamin, cobalamin, in the ileum	-8.2157	8.04E-124
<i>ESRRG</i>	Acts as transcription activator in the absence of bound ligand	-3.1508	6.98E-105
<i>KCNE2</i>	Assembles as a β -subunit with a voltage-gated potassium channel complex of pore-forming α -subunits; modulates the gating kinetics and enhances the stability of the channel complex; associated with KCNH2/HERG, it is proposed to form the rapidly activating component of the delayed rectifying potassium current in the heart; may associate with KCNQ2 and/or KCNQ3 and modulate the native M-type current; may associate with KCNQ1/KVLTQ1 and elicit a voltage-independent current; may associate with HCN1 and HCN2 and increase potassium current	-3.6014	1.29E-97
<i>SST</i>	Somatostatin inhibits the release of somatotropin	-3.1116	3.67E-95
<i>GKN1</i>	Has mitogenic activity and may be involved in maintaining the integrity of the gastric mucosal epithelium	-8.7597	2.11E-91
<i>LIPF</i>	N/A	-8.5977	1.14E-85
<i>CHIA</i>	May participate in the defense against nematodes, fungi and other pathogens; plays a role in T-helper cell type 2 immune response; contributes to the response to IL-13 and inflammation in response to IL-13; stimulates chemokine production by pulmonary epithelial cells; protects lung epithelial cells against apoptosis and promotes phosphorylation of AKT1	-4.1886	1.27E-80

Table V. Continued.

DEG	Function	Fold-change	P-value
<i>DUOX1</i>	Generates hydrogen peroxide, which is required for the activity of thyroid peroxidase and LPO; plays a role in thyroid hormones synthesis and LPO-mediated antimicrobial defense at the surface of mucosa; may have its own peroxidase activity through its N-terminal peroxidase-like domain	-1.9009	1.20E-76
<i>AKR7A3</i>	Can reduce the dialdehyde protein-binding form of AFB1 to the non-binding AFB1 dialcohol; may be involved in protecting the liver against the toxic and carcinogenic effects of AFB1, a potent hepatocarcinogen	-2.1215	1.34E-68
<i>FAM149A</i>	N/A	-1.5039	1.04E-64

DEG, differentially expressed gene; IL-, interleukin; LPO, lactoperoxidase; AFB1, aflatoxin B1; N/A, not available.

Generally, it is accepted that, although the number of dysfunctional genes in a cancer may be limited, a large number of genes in related pathways may be affected at the expression level, and this aberrant gene transcriptional expression network is likely essential in the initiation and maintenance of the malignant phenotype (37-39). Most of the 20 most significantly DEGs have been reported to be involved in the oncogenesis and development of GC (23-26), and the functional classification of these genes was consistent with the results of GO and KEGG analyses. Three genes, including *SPPI*, *TOP2A* and *ARPC1B*, showed the highest connection in the PPI analysis and may have key roles in GC. In addition, *SUL1*, *THBS2*, *HOXC6*, *SST*, *KCNE2*, *GIF*, *GKN1* and *LIPF* were also linked with more than one edge, indicating the potential role of these genes in the pathogenesis of GC.

However, the expression levels of six genes (*MEST*, *GIF*, *CHIA*, *DUOX1*, *KIF4* and *AKR7A3*) in clinical samples were either inconsistent or ignored in previous studies (35,40). In the current study, dysregulation of these DEGs suggests that they serve roles in the oncogenesis and the development of GC. Among the six genes, the associations between GC and *MEST*, *GIF*, *CHIA*, and *DUOX1* have never been reported. *MEST* encodes a member of the α/β hydrolase fold family and has the characteristic of isoform-specific imprinting. The aberrant imprinting of this gene has been linked to certain types of cancer and may be caused by promoter switching (41). *GIF* encodes intrinsic factor (IF), also known as gastric IF, which is a glycoprotein secreted by the parietal cells of the stomach that is necessary for the absorption of vitamin B12 (cobalamin) in the small intestine (35). *CHIA* may participate in the defense against nematodes, fungi and other pathogens, and play a role in the T-helper cell type 2 immune response; it is also involved in the inflammatory response and in protecting cells against apoptosis. Furthermore, *CHIA* is inhibited by allosamidin, suggesting that the function of this protein is dependent on carbohydrate binding (42-45). *DUOX1* is the member of gp91phox homologs family and produces reactive oxygen species in various cells in response to stimuli, including growth factors, cytokines and calcium. A key role for *DUOX1* in lung cancer, but not in GC, has been revealed (46). Although further studies on these genes have not been conducted, the results of the present study suggest that these genes may be considered as novel indicators for GC in the clinic.

Except for the four genes that have not previously been reported in GC, the expression levels of two genes in the current study were different from those reported in previous studies (40,47). Chromokinesin *KIF4* is a member of the *KIF4* subfamily and has been reported as an essential factor involved in multiple cellular process, including cell proliferation, DNA damage responses, immune cell activation, viral protein intracellular trafficking and neuronal survival in brain development (48). The overexpression of this subfamily was reported to inhibit GC cell proliferation *in vitro*, as well as their ability to form tumors *in vivo* (40). However, the expression level of *KIF4* was significantly upregulated in GC samples in the current study. In addition, the expression of *AKR7A3*, which was reported to be upregulated in Singaporean GC patients (47), was downregulated in the RT-qPCR validation in the present study. This discrepancy in the results may be due

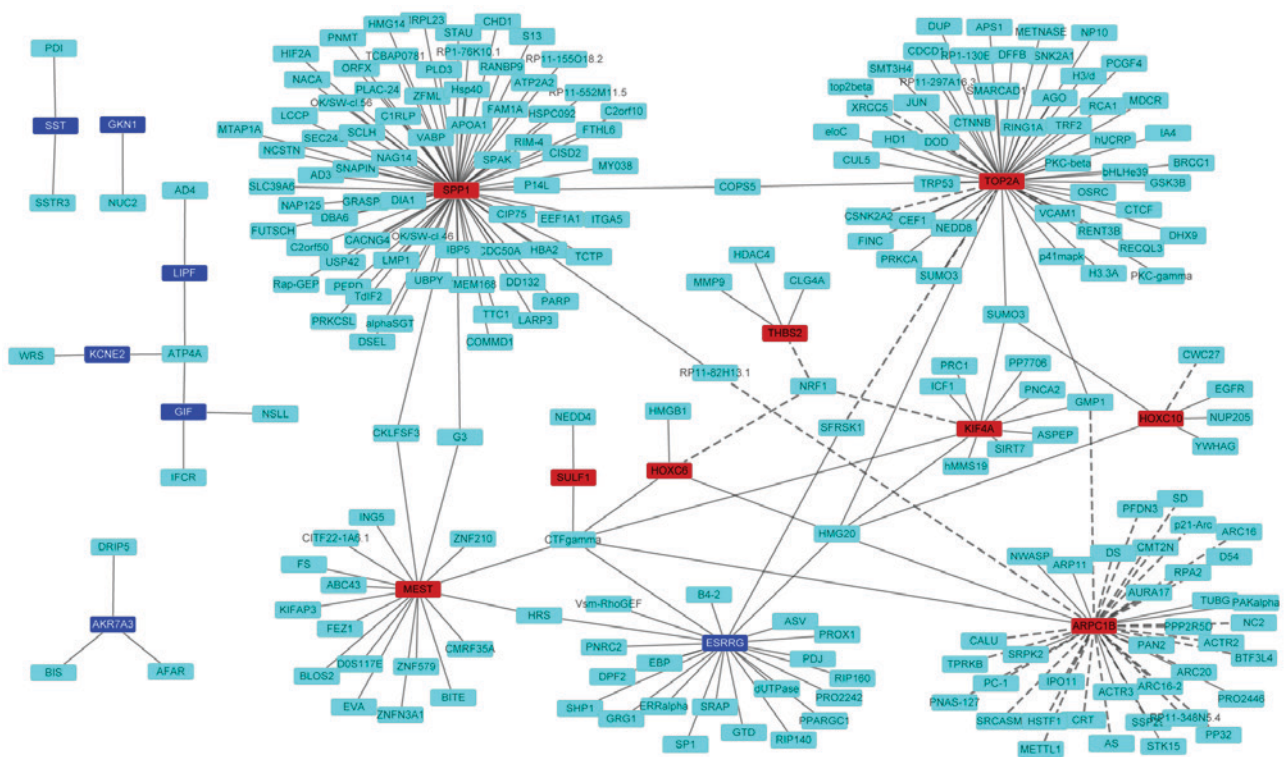


Figure 2. Protein-protein interaction analysis of the top 10 upregulated (red) and downregulated (blue) differentially expressed genes.

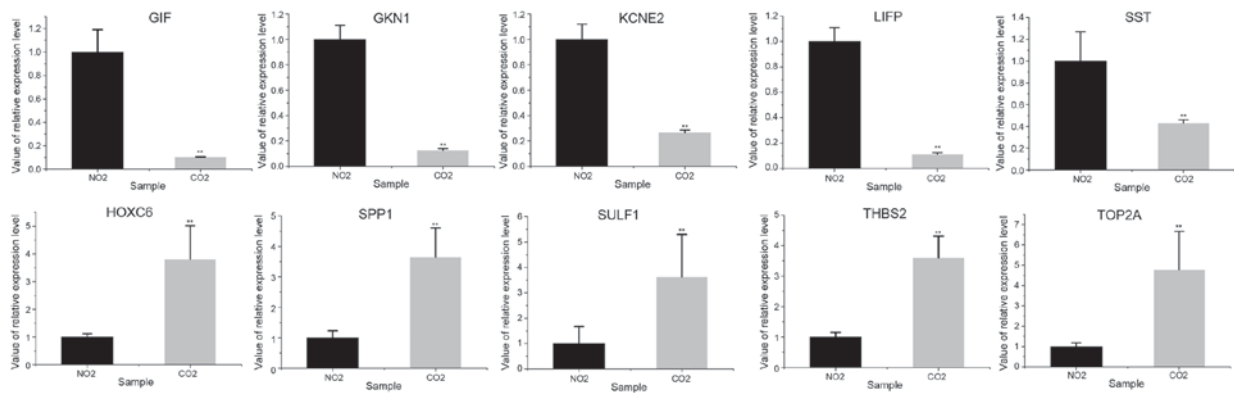


Figure 3. Reverse transcription-quantitative polymerase chain reaction validation of the differentially expressed genes in clinical samples. **P<0.01 vs. the control samples. NO₂, control samples; CO₂, gastric carcinoma samples.

to the heterogeneity of the GEO database, although the results still suggest complicated functions of *KIF4* and *AKR7A3* in the oncogenesis and development of GC.

In conclusion, the current study demonstrated that the analysis of expression profiles and RT-qPCR validation was able to give an explicit elucidation of the dysexpression of genes in GC. However, the results of the analysis of the expression profiles varied from study to study. Based on our results, the expression levels of six genes, including *MEST*, *GIF*, *CHIA*, *DUOX1*, *KIF4* and *AKR7A3*, were found to be inconsistent with previous studies. These genes could potentially be valuable in the clinical treatment of GC. The present study may improve the understanding of the transcriptome status of GC and lay a foundation for further investigation of the mechanisms underlying this cancer of clinical and biological significance.

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