Expression of a novel mRNA in human head and neck squamous cell carcinoma cells

J A Werner, T Görög, B M Lippert, S Gottschlich, K Heidorn, B J Folz, H Rudert

Abstract

Aims—The differential display reverse transcription polymerase chain reaction (DDRT–PCR) technique was used to search for differences between the mRNA expression profiles of squamous cell carcinoma (SCC) cell lines established from head and neck tumours and normal keratinocytes from the mucosa of the upper aerodigestive tract.

Methods—Total RNA prepared from both cell types was reverse transcribed to cDNA then amplified in a PCR mixture. To compare the electrophoretic patterns, mRNAs were amplified by nested PCR using specific oligonucleotides. Additionally, using labelled cDNA probes, northern hybridisation was carried out on three cancer cell lines of different origin, a biopsy from a parotid gland pleomorphic adenoma, healthy mucosa, and keratinocytes.

Results—Comparison of the separated bands revealed a fragment with a differential expression pattern in the SCC cells. This cloned sequence of a 336 base pair mRNA fragment exhibited no significant homology with known transcripts. Additionally, after amplification and sequencing of the 3' end of the fragment no homology with a known human gene sequence was found. However, low homology with a genomic sequence of a nematode was found. Northern hybridisation confirmed the selective expression of this fragment in SCC cells versus the cancer cell lines of different origin, the biopsy of the pleomorphic adenoma, keratinocytes, and healthy mucosa.

Conclusions—This is the first differentially expressed human genome transcript of squamous cell carcinoma of the head and neck identified by DDRT–PCR. It may prove useful, in the future, to characterise this tumour type. (J Clin Pathol: Mol Pathol 1997;50:82–86)

Keywords: squamous cell carcinoma; mRNA expression; differential display reverse transcription polymerase chain reaction

The understanding of malignant diseases has grown in recent years, particularly as a consequence of extensive analysis of gene expression. A number of genes affecting nuclear and cytoplasmic functions have been shown to play an important role in the malignant transformation of cells. Various hybridisation procedures are used for the identification of transcripts present in one sample but not in another. However, these methods are difficult to set up, non-reproducible, and they require large amounts of RNA. In 1992 Liang and Pardee, as well as Welsh et al., developed a technique called differential display, or RNA based arbitrarily primed PCR, to improve and accelerate the identification of differentially expressed genes. For mRNA containing a poly(A) sequence at the 3' end, oligo(dT) nucleotides were used to prime cDNA synthesis. This method was subsequently refined by introducing non-denaturing gels and establishing the appropriate numbers of optimal PCR primers. This improved technique was named differential display reverse transcription polymerase chain reaction (DDRT–PCR). Using this technique, selectively expressed RNA transcripts have been identified in various organisms and in different human tumours. Because the identified fragments can be used for detection and isolation of complete mRNA and cDNA, this method has become an increasingly useful, alternative means for rapid analysis of the selective expression of genes involved in the pathogenesis of various diseases.

Applying the DDRT–PCR technique, we studied squamous cell carcinoma (SCC) cells of the larynx and the floor of the mouth, as well as corresponding normal keratinocytes, to identify and characterise their differential expression of mRNA. We also used specific probes to identify complementary RNA fragments expressed in SCC cells and tumour biopsies.

Methods

CARCINOMA CELLS AND TUMOUR BIOPSIRES

Human head and neck SCC cell lines were studied. Two of the cell lines, UM-SCC-17A and 14B, had been established and characterised by Carey et al., the cell line, Hiac-78, by Zenner et al., the cell line, HCFMK-1, by Görög and normal keratinocytes by Saffran et al. The SCC cell lines were grown in minimum essential medium with Earle's salts and L-glutamine, without addition of non-essential amino acids or sodium bicarbonate, but in the presence of 20 mM Hepes buffer and 10% (vol/vol) fetal calf serum (Biochrome, Berlin, Germany) at 37°C in a 5% CO₂ humidified atmosphere. The keratinocyte cultures were grown in serum free medium (Gibco, Eggenstein, Germany) supplemented with 50 μg/ml bovine pituitary extract and 1.5 ng/ml epidermal growth factor in the presence of 100 U/ml penicillin/streptomycin. Bacterial contamination of the cultures was
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screened by DNA staining as described by Russell et al\(^4\) and by inoculation of the culture medium at 37°C with and without cells.

Two carcinoma biopsies, five normal upper aerodigestive tract mucosa samples, one biopsy of a parotid gland pleomorphic adenoma, RNA from an adenocarcinoma cell line of the lung (HTB-179), the malignant melanoma cell line (HTB-66), and the breast carcinoma cell line (HTB-20) (ATCC, Rockville, USA) were used for northern blotting. The cell lines were grown under the conditions described above. One of the two tumour biopsies subjected to hybridisation was a moderately differentiated SCC of the glottis, the other was a poorly keratinised SCC from the pyriform fossa.

ISOLATION OF TOTAL RNA
For rapid and reproducible preparation of total RNA, the Rneasy Kit (Qiagen, Hilden, Germany) was used in accordance with the manufacturer's instructions. After determination of the RNA content using a spectrophotometer (UVicon 931 UV; Kontron, Hamburg, Germany), samples of total RNA were adjusted to 3.5 μg for subsequent first-strand cDNA synthesis. Quantitative analysis of the mRNA content was carried out using RT–PCR of actin as a control.

FIRST-STRAND CDNA SYNTHESIS
Total RNA (3.5 μg) was heat denatured (65°C, 10 minutes), chilled on ice and subjected to oligo(T) primed reverse transcription using a first-strand cDNA synthesis kit (Pharmacia, Freiburg, Germany). Reverse transcription in a final volume of 33 μl was performed at 37°C for 60 minutes in the presence of 0.2 μM of one of 12 different dodecameric anchored oligo(T) primers (dT\(_{12}\)MN; A, G or C) and 40 units of RNase inhibitor (RNAsin; Gibco). Following synthesis of the completed first-strand cDNA, the resulting double-stranded RNA:cDNA heteroduplex was heat denatured at 95°C for five minutes to provide cDNA as a template for polymerisation.

mRNA DIFFERENTIAL DISPLAY
The first-strand cDNA product (160 μg) was incubated with 0.2 mM of one of 26 decameric arbitrary primers\(^6\), 0.2 μM of the corresponding anchored oligo(T) primer, 2.5 μM dNTPs, 1.5 mM MgCl\(_2\), and 2.5 U Taq polymerase in a total volume of 50 μl. Low-stringency PCR was run for 40 cycles at 95°C for 60 seconds, 40°C for 120 seconds, 72°C for 30 seconds, with a final extension step at 72°C for 10 minutes (Thermocycler 4800; Applied Biosystems, Weiterstadt, Germany). After thermocycling, the amplicons were purified using Qiaquick spin (Qiagen), dried in a vacuum centrifuge, resuspended in 7.0 μl TE buffer\(^5\) and run on a 6% non-denaturing polyacrylamide (PAA) sequencing gel in Mops buffer\(^5\) at 400 V for three hours under constant cooling at 15°C using a flatbed electrophoresis system (EFB-300; Pharmacia). Gels were stained with silver nitrate according to the method of Bassam et al.\(^5\)

ISOLATION, REAMPLIFICATION, AND SEQUENCING OF DIFFERENTIAL DISPLAY
Bands of interest were excised from the gel and the DNA extracted using the Nucleon Easy- clean kit (Scotlab, Wiesloch, Germany). Four microlitres of the DNA elution volume of 50 μl was subjected to PCR under the same conditions as above, except that the concentration of both primers was reduced to 40 pmol. Routinely, 5 μl of the 50 μl reamplified products was separated and stained as above. Purified double-stranded DNA fragments were ligated into the pGEM-T-cloning vector (Promega, Heidelberg, Germany), cloned, and sequenced on a DNA sequencing apparatus (ABI Prism 310; Applied Biosystems).

ANALYTICAL HIGH STRINGENCY NESTED PCR
Following sequencing of the differentially expressed fragment, 5 μl of the first-strand cDNA mixture was subjected to PCR (50 μl) using 2.5 U Taq polymerase, 50 μl PCR buffer (Gibco), 0.2 mM each dNTP, 1.5 mM MgCl\(_2\) and 0.2 μmol of forward and reverse primers. The following primers were used: sense 1, 5'-ATG AAG ATA AAG CAC-3'; antisense 1, 5'-TG GGG GAG GGG GTG-3'; sense 2, 5'-TTG TTG GCC ACC-3'; antisense 2, 5'-GCT TTT TTA CAT-3'. The first PCR was run for 30 cycles with sense 1 and antisense 1 primers and the second for 20 cycles with sense 2 and antisense 2 primers at 94°C for 60 seconds, 58°C for 60 seconds, and 72°C for 120 seconds, with a five minute extension at 72°C. After thermocycling, the amplicons were purified using Qiaquick spin (Qiagen) and 2 μl aliquots of the PCR product were analysed by electrophoresis on a 6% PAA sequencing gel stained with silver nitrate as above.

ONE-SIDED PCR
One-sided or anchored PCR\(^27\) was carried out to amplify the 3' end of cDNA. In this procedure, RNA was extracted and transcribed into cDNA using reverse transcriptase (RT) and an oligo(dT) adaptor primer (Gibco). The cDNA was then amplified by PCR (50 μl) using 2.5 U Taq polymerase, 0.2 mM each dNTP, 5 μl PCR buffer (Gibco), 0.2 μl sense specific primer (SSP) (5'-CAGGGCTCTGCGCCGTATTTG-3') that anneals to a region of the selectively expressed fragment obtained by differential display PCR, and 0.2 μM adaptor primer that targets the poly(A) tail region. The reaction was run for 30 cycles at 94°C for 45 seconds, 55°C for 30 seconds, and 72°C for 90 seconds, with a 10 minute extension at 72°C. Purification, electrophoresis, staining and sequence analysis of the PCR product were carried out as described above.

NORTHERN HYBRIDISATION
The 336 base pair cDNA was random prime labelled using the Dig High prime DNA labelling and detection starter kit II (Boehringer Mannheim, Mannheim, Germany). Twenty micrograms of heat denatured, total RNA from all different cell types and biopsies was separated on 0.8% agarose gels according to...
the method of Sambrook et al. After ethidium bromide staining of 28S and 18S rRNAs, the gels were subjected to capillary transfer on to a positively charged nylon membrane (Boehringer Mannheim) overnight at room temperature. The transferred RNA was subsequently immobilised by UV irradiation, membranes were prehybridised at 50°C for one hour, and hybridised at 50°C for 14 hours in Easy Hyb solution (Boehringer Mannheim). Membranes were then washed twice at room temperature for 15 minutes per wash, in 0.3 mM NaCl, 30 mM sodium citrate (pH 7.0) containing 0.1% (wt/vol) sodium dodecyl sulphate (SDS), and washed twice again for 15 minutes per wash in 70 μM NaCl, 7.0 mM sodium citrate (pH 7.0) containing 0.1% SDS at 68°C. After stringency washes, the membranes were prepared for chemiluminescent detection with disodium 3-(4-methoxyxyspiro[1,2-dioxetane-3,2'-(5-chloro)tricyclo[3.3.1.13.7]decan]-4-yl)phenylphosphate (Boehringer Mannheim) according to the manufacturer’s instructions. Finally, blots were exposed on to x ray film for two to 20 minutes using an intensifier screen.

Results
DIFFERENTIAL EXPRESSION PATTERN
To show the mRNA expression pattern of the cells to be examined, the reverse transcribed cDNA populations were comparatively analysed by DDRT-PCR. Non-denaturing PAA gel electrophoresis could detect selective expression of a 336 base pair mRNA fragment in the head and neck SCC cell line, unlike normal keratinocytes derived from pharyngeal and laryngeal mucosa (fig 1). The reverse transcription step and the PCR reaction for the lane that exhibited a differentially expressed band were repeated and a reproducible difference was corroborated (data not shown). This differentially expressed cDNA fragment was recovered from the gel, reamplified, and cloned into a plasmid vector.

NUCLEOTIDE SEQUENCE OF THE CDNA FRAGMENT
After sequencing of the differentially expressed fragment using both forward and reverse M13 primers, the first 336 bases could be obtained reproducibly. As shown in table 1, the nucleotide sequence begins with a 10mer forward arbitrary primer and ends with the last 10 bases being palindromic to the complementary sequence. The same primer pair generated the sequence presented only a part of the complete mRNA, the polyadenylation signal and the poly(A) tail could not be seen. The sequence was read from the 5' to the 3' end in all three possible reading frames and routinely compared with the GenBank database to identify the differentially expressed fragment. In all instances, there was no exact match with any database sequences (including virus, protokaryote, and eukaryote sequences), suggesting the identification of an unknown transcript. However, a sequence region of 54 base pairs showed 63% homology with the human T cell receptor β locus. This was the highest homology reached for this 336 base pair fragment.

Table 1 Nucleotide sequence of the 694 base pair fragment obtained from head and neck squamous cell carcinoma cells

<table>
<thead>
<tr>
<th>Base pairs</th>
<th>Nucleotide sequence</th>
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<tbody>
<tr>
<td>1-30</td>
<td>TAG AAG GAG GCC ATG AAG ATA AAG CAC TTT</td>
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<tr>
<td>31-60</td>
<td>CTT TTG TTT GGC AGC TGC ATA TCC AAG GAC</td>
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<tr>
<td>61-90</td>
<td>TCC AGA GTA TCC AAC CTT CAA AGC GCT GTG</td>
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<td>91-120</td>
<td>GCT CAT TCC CTG AAC AAG GTG GCC AGG TAC</td>
</tr>
<tr>
<td>121-150</td>
<td>TTC ACA AAG CAA CCC TCT GCA CAC CAC AGT</td>
</tr>
<tr>
<td>151-180</td>
<td>TGG TGC CAG TCT CCA ACA GAA TTT TAC CTC</td>
</tr>
<tr>
<td>181-210</td>
<td>TGG GCC TTA GTT TTT ATT CAG GGC TCC TGC</td>
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<tr>
<td>211-240</td>
<td>CCG ATT TGA ATT ACT TTT GTT AAA</td>
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<tr>
<td>241-270</td>
<td>TGG TGA TTT CTC TAA TCT TAT AAT TCA TTT</td>
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<td>271-300</td>
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<td>AAA AGC TCA TCT GAC GCC CAC CAC CTC</td>
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<tr>
<td>331</td>
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<tr>
<td>337-360</td>
<td>AAG GAA GAT GTA CTT AAT TCC AAG</td>
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<tr>
<td>361-390</td>
<td>GAG TCC GGG CAT TGG TCT TCT GTA TAT TCT</td>
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<tr>
<td>391-420</td>
<td>AAG TCA GAC TCA AAG TTA GCA CCA TAC TAT</td>
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<tr>
<td>671-700</td>
<td>AAA ATG AAA AAA AAA AAA AAA</td>
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The arbitrary 10 base pair primer that was used is underlined. Primers for analytical high stringency nested PCR are highlighted by boldface.
This 234 base pair long sequence may represent the coding region. The 3' end amplified part of the mRNA molecule was then compared again with the GenBank database and a homology of 52% with the gene sequence of the nematode worm Caenorhabditis elegans was found, involving 198 base pairs of the 486 base pair PCR product.

Total RNA from SCC biopsies and cell lines was subjected to northern blot analysis using the differentially expressed 336 base pair digoxygenin labelled probe (fig 2C). Under the same hybridisation conditions, the probe hybridised to an ~ 0.7 kb mRNA from all tumour biopsies and cell lines tested. The HCFMK-1, UM-SCC-14B, and UM-SCC-17A cell lines derived from poorly to well differentiated SCC of the floor of the mouth, as well as the HlaC-78 cell line derived from a moderately to well differentiated SCC of the larynx, all exhibited a high expression rate. The hybridisation signal in the moderately differentiated SCC biopsies from the glottis and in poorly keratinised SCC biopsies of the pyriform fossa was weaker. No expression was detected in either mucosal biopsies, in mucosal keratinocytes cultivated in vitro, in the three cancer cell lines, or in the pleomorphic adenoma of the parotid gland.

Discussion

Major technological advances in recombinant DNA cloning, sequencing, and gene amplification methods have facilitated the use of RNA or cDNA probes in all areas of biomedical research. The differential display PCR technique for gene amplification is a powerful tool and has been used in many aspects of molecular biology, in both research and diagnostic laboratories. The amplification of differentially expressed genes has been used successfully for vertebrates, and for eukaryotic organisms in general. We applied the DDRT–PCR technique to analyse the gene expression profile of cultivated SCC cells and mucosal keratinocytes. Using a protocol for non-radioactive detection that we had recently modified, reproducible cDNA fingerprints were achieved. Compared with differential cDNA library screening or subtractive hybridisation, the differential display technique has several distinct advantages. The procedure is fast, simple, and reproducible. It also has the potential to detect low abundance messages that cannot be detected with conventional hybridisation based approaches.

After reverse transcription of mRNA into cDNA with 3' two-based anchor primers and subsequent amplification with arbitrary primers, we detected a large number of transcripts and isolated a cDNA clone-containing sequence that reacted with all SCC samples, as confirmed by northern hybridisation.

Comparative analysis of the nucleotide sequence of the differentially expressed 336 base pair fragment did not reveal any significant homology with sequences in the DNA database. Furthermore, the sequence of the human T cell receptor β locus showed the highest correspondence, with 63.0% overlap.
ping within a small segment of only 54 base pairs. For further characterisation of this differentially expressed fragment, we attempted to identify the protein coding region. In practice, mRNA transcripts have frequently been detected by the differential display procedure, of which nucleotide sequences represent a 10mer arbitrary primer at one end that is matched by a complementary sequence at the other end. This is due to the nature of the DNA sequence—that is, the same 10mer arbitrary primer anneals to two complementary sequences within the same transcript. Thus, these sequences present neither the polypeptidyl chain nor the poly(A) tail characteristic of mRNA molecules. This is, indeed, the case for the 336 base pair clone which starts with the 5'-TACAACGAGG-3' primer (table 1). The sequence ends with 10 bases (5'-CCTCGGTGTA-3'), of which the complementary sequence is palindromic (3'-GGAGCACAT-5') to the 5' to 3' primer. The lack of added A at the 3' end of cDNA fragments detected by differential display is a well documented fact. Because this fragment was lacking the poly(A) tail, we examined the amino acid sequences of all three possible reading frames but did not find homologous sequences in the protein database. Additional 3' amplification was accomplished by one-sided PCR. The result displayed the stop codons as well as the poly(A) signal of the mRNA. GenBank database comparison was repeated, but again revealed no identity with human gene sequences. This finding suggests that the fragment differentially expressed in laryngeal and floor of mouth carcinoma cells represents a novel gene. Additional analyses, including protein expression studies in bacteriophage expression systems, are in progress to obtain further information regarding the function of this selectively expressed transcript.

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