Detection of herpes simplex virus type 1, 2 and varicella zoster virus DNA in recipient corneal buttons

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Abstract

Aim—To study the value of polymerase chain reaction (PCR) analysis, to detect viral DNA in recipient corneal buttons taken at the time of penetrating keratoplasty (PKP) in patients with an initial diagnosis of herpetic stromal keratitis (HSK). Since HSK has a tendency to recur, an accurate diagnosis of previous HSK could be the reason to start antiviral treatment immediately, thereby possibly decreasing the number of graft failures due to recurrent herpetic keratitis.

Methods—Recipient corneal buttons and aqueous humour (AH) samples were obtained at the time of PKP from HSK patients (n=31) and from other patients (n=78). Eye bank corneas were also used (n=23). Herpes simplex virus type 1 (HSV-1), type 2 (HSV-2), and varicella zoster virus (VZV) infection were assessed by PCR and antibody detection.

Results—The clinical diagnosis HSK could be confirmed by PCR for HSV-1 in 10/31 (32%). In these corneal buttons HSV-2 DNA was detected in 1/31 (3%) and VZV DNA in 6/31 (19%). Intraocular anti-HSV antibody production was detected in 9/28 AH samples tested (32%). In the other patient derived corneas HSV-1 DNA was detected in 13/78 (17%), including eight failed corneal grafts without clinically obvious herpetic keratitis in the medical history. In clear eye bank corneas HSV-1 was detected in 1/23 (4%).

Conclusions—PCR of HSV-1 on corneal buttons can be a useful diagnostic tool in addition to detection of intraocular anti-HSV antibody production. Furthermore, the results were suggestive for the involvement of corneal HSV infection during allograft failure of corneas without previous clinical characteristic signs of herpetic keratitis.

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Deep corneal scar formation is one of the reasons for performing penetrating keratoplasty (PKP). Corneal scars can result from trauma, chemical injury, or corneal ulceration due to pathogenic viruses, bacteria or (other) parasites. Obviously, more than one factor can affect the clarity of the cornea or corneal graft at the same time, including corneal graft rejection. Herpes simplex virus (HSV) infection of the corneal stroma is the most prominent cause of scar formation, impairing visual acuity.

After invading the cornea, herpes viruses can establish latency in the trigeminal ganglion and can be reactivated by stimuli such as sunlight, fever, or severe emotional stress to cause recurrences of ocular disease. HSV infection of corneal grafts could be explained by these HSV recurrences from the sensory ganglion or, less frequently, by newly acquired corneal HSV infection. This could be acquired by transmigration via the donor cornea or by infection from the external environment. Ocular infection with herpes virus may be facilitated by treatment with local corticosteroids for prolonged periods of time. Intraocular HSV infection can be diagnosed by clinical manifestations, reaction to antiviral treatment, or by means of invasive methods. Aqueous humour (AH), obtained by paracentesis of the anterior chamber of the eye can be examined for the presence of antiviral antibodies and by polymerase chain reaction (PCR) techniques to detect viral DNA fragments. Histological examination of all three layers of the cornea is possible after PKP since corneal tissue is excised during PKP. This procedure makes it possible to examine the corneal tissue itself.

Herpetic stromal keratitis (HSK) is thought to be initiated by HSV-1. HSV-1 has been detected in corneas during active and quiescent phases during and after corneal HSV related disease. The roles of HSV-2, usually transmitted by direct sexual contact, and varicella zoster virus (VZV) were less frequently involved in the aetiology of herpetic keratitis than HSV-1.

In this study, a series of recipient corneal buttons, including regrafts, obtained at the time of corneal transplantation, were analysed for the presence of HSV-1, HSV-2, and VZV DNA by PCR.

Materials and methods

PATIENTS AND CONTROLS
This study was approved by the medical ethics committee of the University Medical Centre of Utrecht, Netherlands. The study confirms adherence to the Declaration of Helsinki. Informed consent was obtained from all the patients. Consecutive PKPs were performed in the University Medical Centre, Netherlands (n=328), between 1995 and 1997; corneas and AH samples from 109 PKPs were included in this study. All patients with a previous history of HSK were selected (n=31). These patients had corneal opacification after HSK, which was based on ocular examinations and clinical
Detection of HSV type 1, 2 and VZV DNA in recipient corneal buttons

Table 1  PCR methods

<table>
<thead>
<tr>
<th>Primer pair</th>
<th>[Mg&lt;sup&gt;2+&lt;/sup&gt;] (M)</th>
<th>Annealing temperature (°C)</th>
<th>Product size (base pairs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HSV-1 TK1, TK2</td>
<td>0.002</td>
<td>60</td>
<td>507</td>
</tr>
<tr>
<td>HSV-2 A, B</td>
<td>0.002</td>
<td>66</td>
<td>397</td>
</tr>
<tr>
<td>VZV VZV1, VZV2</td>
<td>0.003</td>
<td>61</td>
<td>274</td>
</tr>
<tr>
<td>VZV VZV3, VZV4</td>
<td>0.003</td>
<td>60</td>
<td>191</td>
</tr>
</tbody>
</table>

VZV-1: 5'-AAT-GCC-GTG-ACC-ACC-AAG-TAT-AAT-3'
VZV-2: 5'-TAC-GGG-TCT-TGC-CGG-AGC-TGG-TAT-3'
VZV-3: 5'-TCC-ATC-TGT-CTT-TGT-CTT-TCA-C-3'
VZV-4: 5'-ATT-TTC-TGG-CTC-TAA-TCC-AAG-G-3'

All primer pairs were tested for the optimal Mg<sup>2+</sup> concentration and annealing temperature (Table 1).

The amplification mixtures contained 100 ng of 3' and 5' primer (Eurogentec, Herstal, Belgium), 0.2 mM of dATP, dCTP, dGTP, and dTTP (Pharmacia Biotech, Leiden, Netherlands), 1 unit of Taq polymerase (Perkin Elmer, NJ, USA), 2.5 µl of template DNA solution, [Mg<sup>2+</sup>] (Table 1), and PCR buffer, containing final concentrations of 0.15M (NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub>, 0.25M KCl, 0.2M NaCl, 0.1M TRIS·HCl, 20 mg/ml bovine serum albumin, pH 8.3, and distilled water in a total volume of 25 µl, covered with mineral oil. One fifth of the first product was amplified using nested primers. The PCR was performed in a Biometra Trio-Thermoblock (Westburg, Leusden, Netherlands) as follows: the samples were denatured at 95°C for 5 minutes, 40 cycles of denaturation for 30 seconds (95°C), primer annealing for 60 seconds at the optimal temperature, and elongation for 90 seconds (at 72°C) were performed. After the last cycle, samples were incubated for 10 minutes at 72°C for additional elongation and stored at 4°C.

The risk of contamination in the PCR was minimised by careful handling of all material, separate rooms for the three stages of PCR were used, dedicated pipettes with plugged tips were used, and guidelines of Kwok and Higuchi were followed. Negative controls were samples composed of sterile water and O and MM. All of these control samples were used in each round of DNA isolation and PCR analysis. Human fibroblasts infected with HSV-1 and HSV-2 strains, VZV, CMV, and CMV strain AD 169 isolated from patients were tested as positive controls (kindly provided by Dr Wertheim of the department of virology of the Academic Medical Centre in Amsterdam, Netherlands). Half of the final PCR product was run on 1.8% agarose gel in 0.5X TBE (45 mM TRIS, 50 mM boric acid and 0.5 mM EDTA, pH 8.3) containing ethidium bromide and photographed. The size of the various PCR products is listed in Table 1.

After denaturation in 0.4 M NaOH for 20 minutes, the DNA was transferred to nylon membranes (Hybond-N, Amersham Life Science, Bucks) by Southern blot analysis in 10X SSC (1.5 M sodium chloride, 0.15 M citric acid, pH 7) overnight. After ultraviolet cross linking (Stratagene UV) the blots were subjected to hybridisation with virus specific probes.

PCR amplification products of HSV-1, HSV-2, and VZV were ligated into the pGEMTeasy vector (Promega, Madison, WI, USA) and used to transform Escherichia coli JM 109. Twenty transformants were subjected to PCR analysis with virus specific primers. For
each virus, DNA from overnight cultures of cloned inserts were isolated and purified using a DNA purification kit for electrophoresis (Qiagen, West Sussex, UK). The nucleotide sequence was checked for correctness by manual sequencing by the dideoxy method and computer assisted analysis (BLAST searches on EMBL, GenBank). Approximately 50 ng of each insert was radioactively labelled with 20 µCi [α-32P]-dCTP (3000 Ci/mMol), 1 mM of each deoxythymidine triphosphate, deoxyguanosine triphosphate, deoxyadenosine triphosphate, 2 µl hexanucleotides (Boehringer, Mannheim, Germany), and 2 units Klenow (Boehringer) at 37°C for 1 hour. This mixture was separated on a Sephadex column G-50 (Pharmacia, Sweden). Hybridisation of above mentioned Southern blots was performed overnight at 65°C in 6X SSC, 5x Denhardt’s reagent, and 100 µg/ml sheared denatured herring sperm DNA. After hybridisation, filters were washed twice at 65°C in 0.2X SSC-0.1% sodium dodecyl sulphate. Filters were exposed to x ray film at −70°C overnight.

The detection limits of each round of PCR were determined using known amounts of plasmid DNA, deduced from the optical density at 260 nm, containing the HSV-1, HSV-2, or VZV specific fragments. In the nested HSV-1 DNA PCR 10² of template copies could be detected, in the HSV-2 DNA PCR 10³ copies, and in the nested VZV DNA PCR 10³ of template copies could be detected. No cross reactivity between each of the primer sets and positive controls for HSV-1, HSV-2, VZV, or human DNA was observed.

INTRAOCULAR ANTI-HSV ANTIBODY PRODUCTION

Antibody titres against HSV-1 and 2 and against VZV in AH and sera were assessed by means of commercially available ELISA plates (Gull, ‘s Hertogenbosch, Netherlands), according to the manufacturers’ instructions. These were compared with the total immunoglobulin content in AH and serum by standard Mancini tests. This ELISA did not discriminate between HSV-1 or HSV-2. The Goldmann–Witmer coefficient (GWc), a measure for intraocular antibody production against HSV (1 and 2) and VZV was calculated. A GWc of greater than 3 was considered to be positive.

STATISTICAL ANALYSIS

The results of the HSV-1 PCR were analysed using the χ² statistics, to compare two groups with non-parametrical distributed data. The difference in time periods between the last episode of HSK to PKP in the group with positive PCR results for HSV-1 and negative PCR results for HSV-1 was analysed with the Mann–Whitney test.

Results

In this study, corneal HSV infection was assessed in corneal tissue and in AH samples, obtained during PKP. In patients with a previous history of HSK, HSV-1 DNA was detected (Fig 1) in 10 out of 31 recipient corneal buttons (Table 2) and in five additional cases, a positive GWc for HSV was observed (Table 3). Therefore, the diagnosis of previous HSK could be confirmed in 15 out of 31 cases (48%) with the combination of tests used in this study. The time that elapsed from the last clinical episode or recurrence of HSK until the moment of PKP was significantly shorter in the corneas in which HSV-1 was detectable (on average 30 months) than those negative for HSV-1 (on average 124 months, Fig 2).

In six corneal samples, the PCR for both HSV-1 and VZV were positive and one corneal sample yielded a positive PCR result for HSV-1, HSV-2 and VZV, indicated in Table 2. Noteworthy was the large number of HSV-1 positive samples in failed corneal grafts and unspecified ulcers (11 out of 26, 42%), without a clinical history of HSK. The frequency of positive HSV-1 PCR results in this group (n=26) was significantly higher compared with the other patient derived corneas (n=52), p=0.003 (Table 2). The clinical signs that appeared during the process of graft failure had not been suggestive for herpetic keratitis and antiviral treatment had not been applied. In this group, HSV-1 DNA was detected in eight out of 17 corneal buttons (47%), HSV-2 in none (0/17), and VZV in one out of 17 grafts.
In corneas with healed non-specified ulcers, in which a bacterial or neurotrophic cause was presumed, HSV-1 DNA was present in three out of nine corneal buttons (33%) and VZV DNA in one out of nine (11%).

In the recipient corneal buttons of the other patient groups, without any previous clinical HSV related ophthalmological symptoms (n=52), only two corneas seemed to be infected with HSV-1, as well as with VZV. In four other corneas the PCR for VZV was positive.

Eye bank corneas without visible scars were provided for investigation after the endothelial cell count had been determined and found insufficient for transplantation purposes. HSV-1 DNA was detected in only one out of 23 DNA samples. The number of positive results in the HSV-1 PCR in the group with previous HSK (n=31) was significant compared with eye bank derived corneas (n=23), p=0.012 (Table 2).

In Table 3, additional results of herpes virus PCR analysis and anti-HSV antibody production in AH samples obtained at the time of PKP, are presented. It appeared that the PCR for HSV-1 remained negative in all AH samples; whereas antibody production against HSV was detected in 12 samples, including nine from patients with a history of HSK or allograft failure. In case of a negative PCR for HSV-1 in the corneal button, anti-HSV-1 antibody production in AH was of additional value for the confirmation of the diagnosis of previous HSK. Anti-HSV antibody production in AH could not be observed in any of the patients with corneal ulcers of non-HSK related disease.

**Discussion**

Intraocular HSV-1 infection could be confirmed in 15 out of 31 patients with a clinical history of HSK (48%). A positive test result in the HSV-1 PCR was obtained in 10 out of 31 cornea samples and anti-HSV antibody production in AH was detectable in five additional cases.

In this study, primers for the thymidine kinase gene of HSV-1 were applied and in 10 out of 31 (32%) of the HSK patients, HSV-1 was detected in the recipient corneas. The same primers were reported to yield a positive result in eight out of 11 corneal DNA samples (73%).

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**Table 2** Detection of HSV-1, HSV-2, and VZV specific DNA fragments by PCR analysis on cornea derived DNA

<table>
<thead>
<tr>
<th>Diagnosis at PKP</th>
<th>No</th>
<th>HSV-1</th>
<th>HSV-2</th>
<th>VZV</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>positive: 8</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>negative: 12</td>
<td>0</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td></td>
<td>positive: 2</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>negative: 9</td>
<td>0</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>positive: 8</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>negative: 9</td>
<td>0</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>positive: 3</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>negative: 6</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>positive: 2</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>negative: 50</td>
<td>0</td>
<td>3</td>
</tr>
</tbody>
</table>

*Three dual infections and two single VZV infections; †triple infection; ‡dual infections.

**Table 3** HSV-1 antibodies and HSV-1 DNA in aqueous humour at the time of perforating keratoplasty

<table>
<thead>
<tr>
<th>Diagnosis at PKP (n)</th>
<th>PCR HSV-1 in corneal button</th>
<th>PCR HSV-1 in* aqueous humour</th>
<th>Intraocular anti HSV†‡ antibody production</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>positive: negative:</td>
<td>positive: negative:</td>
<td>positive: negative:</td>
</tr>
<tr>
<td>HSK, primary graft (20)</td>
<td>8</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>Allograft failure with initial HSK diagnosis (11)</td>
<td>2</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Allograft failure with initial non-HSK diagnosis (17)</td>
<td>9</td>
<td>0</td>
<td>7</td>
</tr>
<tr>
<td>Ulcers, non-specified (9)</td>
<td>8</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>Other diagnosis, non-HSK (52)</td>
<td>9</td>
<td>0</td>
<td>8</td>
</tr>
</tbody>
</table>

*In a great number of cases, the amount of AH was insufficient to detect antibody production and perform PCR; †the ELISA did not discriminate between HSV-1 and HSV-2; ‡in 1 case the GWc for VZV was also positive.

Figure 2 Cases with positive PCR results in the PCR for HSV-1 had significantly shorter time periods between the last episode of HSK and PKP than cases with negative PCRs (Mann–Whitney test, p=0.004). The median time period was 10 months (range 1–125 months) with positive HSV-1 PCRs and 41 months (range 11–210 months) with negative PCRs.
in our study (n=31) was, however, larger and the
time period from the last HSK recurrence until PKP, which would undoubtedly
have affected the number of positive cases, was not
mentioned in the study of Cantin. 15 The choice
of which DNA fragment of the HSV-1 genome
is to be multiplied influences the sensitivity of
the PCR. Other parts of the HSV-1 genome
have also, although less frequently, been
applied for the detection of HSV-1. The UL-42
gene was detected in 14 out of 47 samples
(30%), the glycoprotein D gene in eight out of
18 (44%) 16 , and a shared DNA-polymerase
gene by HSV type 1 and type 2 14 in five out of
eight (63%). 16
HSV can remain present in the cornea after
HSK disease 14-17 and some studies report the
possibility of HSV latency in the cornea. 17 18 27
Withdrawal of the virus in the draining sensory
trigeminal nerve is, however, more plausible
with the lapse of time. 1 3 26 The detection
frequency of HSV-1 DNA decreased starting 6
months after experimental corneal HSV infec-
tion in rabbits. 26 Similarly, in our study, HSV-1
DNA was found less frequently, with an
increasing time interval from the last episode of
HSK until sampling of the corneal button.
Negative results in the PCR for HSV, in
corneae derived from patients with a history of
HSK may be explained by previous treatment
with local and oral antiviral medication, inhibit-
ing HSV, 26 or by a critically small number of
HSV DNA copies in the test sample, below
detection limits of the PCR assay.
In patients with allograft failure without a
history of HSK, an unexpected high number of
HSV-1 positive recipient corneal buttons were
found. In these patients, no antiviral treatment
was used since no obvious clinical signs of cor-
neal HSV infection had been observed during the
process of graft failure. Some clinical expression
forms of HSV induced corneal dis-
ease may be difficult to recognise. Furth-
more, transmission of HSV through donor cor-
neas can not be excluded. 11
In systemically immunosuppressed patients,
HSV infections appeared to occur more
frequently. 30 The application of local immuno-
suppressive eye drops may have a similar effect
on corneal HSV infections. Besides the neces-
sary application of local immunosuppression in
recently cornea grafted eyes, the grafting
procedure itself was identified as a stimulating
factor for recurrences of corneal HSV infec-
tion. 11 Local corticosteroids in the ab-
sence of antiviral medication, also increased
the severity of intraocular HSV infection. 31 In
view of the difficulty of distinguishing herpes
simplex infection from corneal allograft rejec-
tion and the great number of positive results
for HSV in allograft failures without previous
signs of herpetic keratitis in this study, it may be
advisable to couple antiviral therapy with corticosteroid treatment in cases of an
immunologically mediated corneal graft opacifica-
tion process. 11
The patients with non-specified ulcers (pre-
viously treated elsewhere) and positive PCR
results for HSV-1 in the corneal button are illustrative of the need for more adequate diag-
nostic procedures, at the time of corneal
disease.
Positive results of HSV-1 in corneal DNA
samples from patients without clinical herpetic
keratitis in their medical history were unlikely
to be the result of careless handling. 22 In
culture fluids and rims of healthy donor
corneas HSV-1 DNA has been detected 10 and
a study reported transmission of corneal HSV
infection to the recipient. 7 Other explanatory
factors for HSV-1 in control corneas may be
subclinical HSV infection or the existence of
less virulent virus strains. 7
All PCRs for HSV-1 in AH samples
remained negative, probably because all PKPs
were performed during a quiescent phase of
corneal disease. Viral DNA was detectable
only shortly in an early phase of ocular HSV
infection and anti-HSV antibody production
for a prolonged period of time. 11 In our study,
antibody production against HSV was detected
in nine cases with previous HSK, and in three
cases of allograft failure without previous
HSK. A positive test result in the GWc for
HSV was found six times in cases with negative
HSV-1 PCR results in the corneal button.
Therefore, determination of the GWc for HSV
in AH was of additional value in making the
diagnosis of previous intraocular HSV infec-
tion.
HSV-2 and VZV were examined in the same
corneal samples and VZV in the same AH
samples. The PCR for HSV-2 was positive in
two cases, one regraft with previous HSK and
one cornea with BKP. HSV-2 has been
detected in corneas with previous herpetic
keratitis, 19 but in other studies using PCR
analysis HSV-2 could not be detected. 14 16
HSV-2 is evidently capable of invading body
sites outside the urogenital tract, which has
been described earlier. 19 Ocular VZV infection
often coexists with HSV-1 infection, although
keratitis with primary VZV infection has been
reported. 15 Recurrence of VZV infection often
gives rise to pain and skin lesions in the
affected dermatome. These signs were not
observed in the patients with the few corneas in
which the PCR for VZV was positive. The
primer sequences for the three viruses were
chosen carefully to avoid cross reactivity. Also,
the possibility of contamination by handling of
corneas and AH samples was minimised by
careful handling during surgery, transport, and
in the laboratory. 22
In summary, at the time of PKP the diagno-
sis of previous corneal HSV infection can be
made by PCR for HSV-1 on the corneal button
and determination of antibody production
against HSV in AH. Determination of the
GWc for HSV in AH is of more value than per-
forming PCR for HSV in AH at this stage. The
results suggest herpetic keratitis can not only
be caused by HSV-1 infections but might also
be caused by infection with HSV-2 or mixed
infections with HSV-1, HSV-2, and VZV. Fur-
thermore, HSV DNA in the cornea and
anti-HSV antibodies were present in a number
of failed corneal grafts without previous signs
of herpetic keratitis. Therefore, HSV-1 ap-
ppeared to be involved in the process of irrevers-
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