Geographic variations in microbial keratitis: an analysis of the peer-reviewed literature

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ABSTRACT

The epidemiology of microbial keratitis has been investigated in several studies by analysis of organisms cultured from corneal scrapes. However, a comparison of the frequency of different organisms causing keratitis in different parts of the world is lacking. The authors present a review incorporating an analysis of data from studies worldwide. The data provide a comparison of the frequency of culture-positive organisms found in different parts of the world. Associations between a country's gross national income and types of causative organism are explored. The highest proportion of bacterial corneal ulcers was reported in studies from North America, Australia, The Netherlands and Singapore. The highest proportion of staphylococcal ulcers was found in a study from Paraguay, while the highest proportion of pseudomonas ulcers was reported in a study from Bangkok. The highest proportions of fungal infections were found in studies from India and Nepal. The Spearman correlation coefficient demonstrated statistically significant correlations between gross national income and percentages of bacterial (0.85 (95% CI 0.68 to 0.91, $p<0.0001$)), fungal (−0.81 (95% CI −0.90 to −0.66, $p<0.0001$)) and streptococcal (−0.43 (95% CI −0.66 to −0.12, $p=0.009$)) isolates.

INTRODUCTION

Microbial keratitis is a potentially serious corneal infection and a major cause of visual impairment worldwide. A conservative estimate of the number of corneal ulcers occurring annually in the developing world alone is 1.5–2 million.[1] Permanent visual dysfunction has been reported in a significant proportion of patients in both developing[2] and developed[3] countries. Srinivasan *et al*[4] comment that ulceration of the cornea in south India 'is a blinding disease of epidemic proportions.'

Various micro-organisms can cause microbial keratitis, and predisposing risk factors vary from one geographic region to another. They include pre-existing corneal disease as well as other risk factors such as contact-lens wear, surgical or non-surgical trauma, and ocular surface disease.[5–7]

There is limited comparative information on international patterns of causative organisms in microbial keratitis. With increasing rates of migration and international travel, an awareness of these geographical variations is relevant for clinicians treating microbial keratitis, and especially for those planning to work in regions where they have not previously practised. The aim of this review is to summarise the published literature that provides information on the worldwide variation in organisms causing microbial keratitis.

METHODS

Search strategy

A systematic review of the current literature pertaining to the prevalence of causative organisms responsible for microbial keratitis was conducted. PubMed searches were performed and verified in April 2009 by two independent investigators. The terms 'microbial keratitis,' 'bacterial keratitis' and 'infectious keratitis' were entered into PubMed. Only papers presenting data that were collected after 1 January 1990 were examined, and the search was restricted to English language and human studies. Only studies that cultured at least 50 organisms in total were included. Titles and abstracts were read, and a judgement was made as to whether the paper provided culture results for microbial keratitis in a specified geographical location. If this was felt to be the case, a full text request was made to access the original published data.

Studies looking only at infections related to use of contact lenses were excluded, as were studies looking only at limited age groups.

Extraction and recording of data

Papers were read, and information was abstracted on the following variables: number of patients in the study, time period of reporting, region, method by which organisms were isolated, method of culture, rate of positive cultures and number of contact-lens wearers in the study sample. These data were then entered into a Microsoft Excel spreadsheet.

With regard to the micro-organisms cultured, the total numbers in each of the following categories were abstracted and recorded: Gram-positive organisms—staphylococcal species and streptococcal species; Gram-negative organisms—Pseudomonas species; protozoa; fungi/yeasts—Aspergillus species and Candida species.

Classification of income levels and GNI subheading

The prevalence of different causative organisms was compared according to countries' gross national incomes (GNIs) (source=http://web.worldbank.org). Income groups were defined by 2007 GNI per capita, calculated using the World Bank Atlas method.[8] The groups distinguished were: low income, $935 or less; lower middle income, $936–$3705; upper middle income, $3706–$11 455; and high income, $11 456 or more.

Statistical analysis

Statistical analysis was performed using 'Analyse-it' version 2.20 software. Spearman correlation coefficients were used to explore associations:

1. between prevalence of certain types of organism and GNI; and

Table 1 Studies meeting criteria for inclusion in review

Location of study (reference)	Gross national income per capita ($)	Time period (months)	No of patients	Proportion (%) of patients using contact lenses	Method of culture	Proportion (%) of patients with positive cultures
Africa						
Ghana[12]	590	24	290	Unspecified	Sheep's blood agar, Sabouraud broth, inhibitory mould agar, brain–heart infusion broth, chocolate agar and cysteine tryptone agar	50
Accra, Ghana[13]	590	Unspecified	199	Unspecified	Chocolate, Sabouraud	64
Indian subcontinent						
Nepal[14]	340	36	447	Unspecified	Sheep's blood agar, chocolate, brain–heart infusion, Sabouraud	68
Chittagong, Bangladesh[15]	470	Unspecified	151	Unspecified	Blood, chocolate, thioglycolate, Sabouraud	63
Tamil Nadu, India[12]	950	24	800	Unspecified	Sheep's blood agar, Sabouraud broth and Sabouraud glucose agar, brain heart infusion broth, chocolate, cysteine tryptone agar	69
West Bengal, India[10]	950	36	1198	0.33	Blood, chocolate, potato dextrose agar, Sabouraud dextrose	68
New Delhi, India[2]	950	Unspecified	100	2.0	Blood, chocolate, thioglycolate, Sabouraud	65
Madurai, India[4]	950	3	434	Unspecified	Sheep's blood agar, potato dextrose agar, chocolate, brain–heart infusion	68
Hyderabad, India[16]	950	95	1092	Unspecified	Sheep's blood agar, chocolate, non-nutrient, Sabouraud, brain–heart infusion, potato dextrose agar	35
Tamil Nadu, India[17]	950	36	3183	1.04	Unspecified	71
Hyderabad, India[18]	950	15	170	Unspecified	Unspecified	69.4
Delhi, India[19]	950	12	1000	8.2	Unspecified	56.8
Riyadh, Saudi Arabia[20] ‡	15 440	12	103	17.48	Blood, chocolate, Sabouraud and thioglycolate	Unspecified for 2005‡
Baghdad, Iraq[21] †	2320	36	394	6.09	Blood, chocolate, Sabouraud and brain–heart infusion	58.6
South America						
Asuncion, Paraquay[22]	1670	162	660	Unspecified	Blood, chocolate thioglycolate, Sabouraud	79
Far East						
Taipei, Taiwan[23]	16 590	120	453	44.3*	Chocolate, sheep's blood agar, Sabouraud	56
Taipei, Taiwan[24]	16 590	12	314	9.9	Blood, chocolate, thioglycolate, brain–heart infusion	43
Singapore[25]	32 470	60	80	22.5	Blood, chocolate, thioglycolate, Sabouraud, brain–heart infusion	100
Singapore[26]	32 470	22	103	34	Blood, chocolate, thioglycolate, Sabouraud	50
Hong Kong[5]	31 610	17	223	26.5	Blood, chocolate, thiogylcolate, Sabouraud, non-nutrient Page's saline agar	35
Bangkok, Thailand[27]	34 000	47	127	24.4	Blood, chocolate, thioglycolate	100
Australasia						
Auckland, New Zealand[3]	28 780	24	98	26	Blood, Sabouraud, thioglycolate, brain–heart infusion, Page's amoebic saline	71
Christchurch, New Zealand[28]	28 780	60	78	Unspecified	Sheep's blood agar, chocolate	59
Adelaide, Australia[29]	35 960	61	211	Unspecified	Blood, chocolate, Sabouraud	64
Victoria, Australia[7]	35 960	24	291	33.7	Chocolate, Sabouraud	49
Brisbane, Australia[6]	35 960	60	231	22.9	Blood, MacConkey, chocolate, Sabouraud	65
North America and Canada						
Toronto, Canada[30]	39 420	25	95	11.6	Blood, chocolate, inhibitory mould agar, thioglycolate	63
Miami, USA[31]	46 040	108	2920	10.4*	Chocolate, sheep's blood agar, Sabouraud, thioglycolate	50
Pittsburgh, USA[32]	46 040	60	825	Unspecified	Sheep's blood agar, chocolate, mannitol salt agar, Sabouraud dextrose agar supplemented with gentamicin	100
Los Angeles, USA[33]	46 040	31	81	Unspecified	Blood, chocolate, thioglycolate, Sabouraud	76
Texas, USA[34]	46 040	60	131	28.8	Chocolate, blood, thioglycolate, Sabouraud dextrose	52.5
Durham, USA[35]	46 040	84	453	Unspecified	Blood, chocolate, Sabouraud, thioglycolate	68
Europe						
Paris, France[11]	38 500	21	291	50.3*	Chocolate polyvitex agar, Schaedler broth with globular extract, Portagerm-Amies agar swab, Sabouraud-chloramphenicol-gentamicin medium	68
Laussanne, Switzerland[36]	59 880	21	85	36	Blood, Sabouraud, chocolate, brain–heart infusion	86
Anatolia, Turkey[37]	8020	192	620	3.2	Chocolate, blood agar, Sabouraud	48.4
Amsterdam and Rotterdam[38]	45 820	36	156	39.74	Blood agar, chocolate agar, cooked meat broth, Sabouraud agar	58

*Paper did not specify the number of contact-lens wearers. Instead, the authors report on the number of isolates from contact-lens wearers. The figure given in the table therefore represents the percentage of isolates retrieved from cases where contact-lens wear was a risk factor.
†Estimated to be lower middle income ($936 to $3705); the value given in the table is the midpoint of this range.
‡This paper presented data for 1995 and 2005; only 2005 data have been extracted in our study.

2. between prevalence of contact-lens wear and prevalence of pseudomonas.

RESULTS

A total of 3883 publications were identified through the preliminary PubMed search. Of these, 37 papers met the inclusion criteria. One paper was excluded because it included a significant number of cases that the authors deemed to constitute an outbreak of suture-related infections.[9] Twelve of the included papers were from the Indian subcontinent, seven from North America and Canada, six from the Far East, five from Australasia, four from Europe, two from Africa (both from Ghana) and one from South America. The median GNI of the countries studied was $22 685 (range $470–$59 880). The number of patients ranged from 73 to 3183. The time periods of study ranged from 3 to 192 months, although three studies did not specify the study period. The proportion of keratitis patients with a recent history of contact-lens wear was reported in only 22 studies and ranged from 0.33% (West Bengal[10]) to 50.3% (Paris[11]). Three studies reported on only culture-positive cases and so appear to have 100% culture-positive rates in table 1. In the remainder of the studies, culture-positive rates ranged from 35% to 86%.

Bacterial isolates from each study are summarised in table 2. Among studies which looked at non-bacterial as well as bacterial organisms, Los Angeles[33] and Adelaide[29] had the highest percentages of bacterial cases (95% in both), with Paraguay[22] having the highest percentage of staphylococcal species (79%), and Bangkok[27] the highest proportion of pseudomonal infections (55%). Tamil Nadu[12] had the highest percentage of streptococcal infections (47%). The highest percentage of protozoal infections (7%) was found in a study from Hong Kong.[5]

Table 2 Bacterial isolates by location

	No of isolates (percentage of total isolates from that location)						
	Gram-positive bacteria				Gram-negative bacteria		
Location of study	Any	Staphylococci	Streptococci	Other	Any	Pseudomonas	Other
Africa							
Ghana	17 (11.3)	4 (2.7)	8 (5.3)	5 (3.3)	21 (14.0)	21 (14.0)	0 (0)
Accra, Ghana	34 (26.2)	18 (13.8)	11 (8.5)	5 (3.8)	29 (22.3)	17 (13.1)	12 (9.2)
Indian subcontinent							
Nepal	136 (38.0)	102 (28.5)	31 (8.7)	3 (0.8)	21 (5.9)	18 (5.0)	3 (0.8)
Chittagong, Bangladesh	27 (21.3)	2 (1.6)	23 (18.1)	2 (1.6)	39 (30.7)	34 (26.8)	5 (3.9)
Tamil Nadu, India	178 (33.1)	63 (11.7)	110 (20.4)	5 (0.9)	57 (10.6)	35 (6.5)	22 (4.1)
West Bengal, India	214 (23.1)	174 (18.8)	28 (3.0)	12 (1.3)	84 (9.1)	63 (6.8)	21 (2.3)
New Delhi, India	35 (53.8)	28 (43.1)	2 (3.1)	5 (7.7)	17 (26.2)	10 (15.4)	7 (10.8)
Madurai, India	132 (40.6)	26 (8.0)	76 (23.4)	30 (9.2)	35 (10.8)	24 (7.4)	11 (3.4)
Hyderabad, India	198 (50.9)	92 (23.7)	60 (15.4)	46 (11.8)	45 (11.6)	27 (6.9)	18 (4.6)
Tamil Nadu, India	814 (34.0)	259 (10.8)	492 (20.6)	63 (2.6)	325 (13.6)	236 (9.9)	89 (3.7)
Hyderabad, India	80 (67.2)	43 (36.1)	27 (22.7)	0 (0)	13 (10.9)	6 (5.0)	7 (5.9)
Delhi, India	223 (30.6)	200 (27.4)	10 (1.4)	13 (1.8)	152 (20.9)	88 (12.1)	64 (8.8)
Riyadh, Saudi Arabia	130 (73.9)	75 (42.6)	26 (14.8)	29 (16.5)	45 (25.6)	16 (9.1)	29 (16.5)
Baghdad, Iraq	88 (37.3)	70 (29.7)	15 (6.4)	3 (1.3)	74 (31.4)	68 (28.8)	6 (2.5)
South America							
Asuncion, Paraquay	278 (69.0)	210 (52.1)	42 (10.4)	226 (56.1)	132 (32.8)	46 (11.4)	96 (23.8)
Far East							
Taipei, Taiwan	67 (26.6)	21 (8.3)	21 (8.3)	25 (9.9)	120 (47.6)	95 (37.7)	25 (9.9)
Taipei, Taiwan	57 (35.0)	39 (23.9)	12 (7.4)	6 (3.7)	106 (65.0)	56 (34.4)	50 (30.7)
Singapore	Unspecified	4 (5.0)	4 (5.0)	Unspecified	41 (51.3)	23 (28.8)	18 (22.5)
Singapore	9 (16.4)	5 (9.1)	4 (7.3)	0 (0.0)	42 (76.4)	23 (41.8)	19 (34.5)
Hong Kong	37 (41.1)	9 (10.0)	3 (3.3)	25 (27.8)	42 (46.7)	28 (31.1)	14 (15.6)
Bangkok, Thailand	23 (17.7)	11 (8.5)	12 (9.2)	0 (0.0)	Unspecified	43 (33.1)	Unspecified
Australasia							
Auckland, New Zealand	75 (57.3)	41 (31.3)	11 (8.4)	13 (9.9)	13 (9.9)	7 (5.3)	6 (4.6)
Christchurch, New Zealand	45 (71.4)	19 (30.2)	11 (17.5)	15 (23.8)	18 (28.6)	2 (3.2)	16 (25.4)
Adelaide, Australia	89 (66.4)	65 (48.5)	12 (9.0)	12 (9.0)	38 (28.4)	17 (12.7)	21 (15.7)
Victoria, Australia	72 (63.2)	56 (49.1)	8 (7.0)	8 (7.0)	29 (25.4)	10 (8.8)	19 (16.7)
Brisbane, Australia	75 (39.9)	41 (21.8)	11 (5.9)	23 (12.2)	56 (29.8)	44 (23.4)	12 (6.4)
North America and Canada							
Toronto, Canada	43 (66.2)	32 (49.2)	10 (15.4)	1 (1.5)	20 (30.8)	7 (10.8)	13 (20.0)
Miami, USA	637 (47.6)	278 (20.8)	89 (6.7)	270 (20.2)	664 (49.6)	345 (25.8)	319 (23.8)
Pittsburgh, USA	797 (75.7)	638 (60.6)	115 (10.9)	44 (4.2)	256 (24.3)	71 (6.7)	185 (17.6)
Los Angeles, USA	48 (58.5)	34 (41.5)	9 (11.0)	5 (6.1)	30 (36.6)	13 (15.9)	17 (20.7)
Texas, USA	45 (43.3)	25 (24.0)	12 (11.5)	8 (7.7)	32 (30.8)	18 (17.3)	14 (13.5)
Durham, USA	314 (80.9)	197 (50.8)	57 (14.7)	78 (20.1)	74 (19.1)	40 (10.3)	34 (8.8)
Europe							
Paris, France	172 (83.1)	116 (56.0)	19 (9.2)	37 (17.9)	35 (16.9)	21 (10.1)	14 (6.8)
Laussanne, Switzerland	57 (76.0)	45 (60.0)	10 (13.3)	2 (2.7)	18 (24.0)	7 (9.3)	11 (14.7)
Anatolia, Turkey	155 (68.9)	115 (51.1)	35 (15.6)	5 (2.2)	20 (8.9)	15 (6.7)	5 (2.2)
Amsterdam and Rotterdam	46 (41.4)	25 (22.5)	16 (14.4)	5 (4.5)	58 (52.3)	35 (31.5)	23 (20.7)

Protozoal and fungal/yeast isolates from each study are summarised in table 3. Eastern India[10] had the highest proportion of corneal infections attributable to fungi (67%). When considering those countries with a significant proportion of fungal ulcers (we have arbitrarily chosen a cut-off of 10% or more), East India also had the highest percentage of aspergillus (60% of all fungal cultures), whereas the highest percentage of fusarium (73% of all fungal cultures) was found in a study from Hyderabad.[18]

Statistically significant correlations were found between GNI and percentages of bacterial, fungal (see figures 1, 2) and streptococcal isolates (data not shown). The Spearman correlation coefficient for prevalence of bacteria and GNI was 0.85 (95% CI 0.68 to 0.91, $p<0.0001$), for prevalence of fungi and GNI −0.81 (95% CI −0.90 to −0.66, $p<0.0001$) and for prevalence of streptococci and GNI −0.43 (95% CI −0.66 to −0.12, $p=0.009$). Surprisingly, there was no statistically significant correlation between percentage of pseudomonal isolates and percentage of contact-lens wearers.

DISCUSSION

We have found a wide variation in the causative organisms for microbial keratitis in different parts of the world. To some degree, this variation is explained by economic factors as well as contact-lens wear. A high proportion of bacterial ulcers were reported from centres in developed countries (North America, Australia and Western Europe). In these countries, patients are far less likely to be agricultural workers, and so have a reduced risk of trauma from organic matter, which is known to be a risk factor for fungal infection.[25]

A high percentage of staphylococcus species (79%) was recorded in the study from Paraguay,[22] although the reason for this is not clear. Of note, the authors comment that their

Table 3 Protozoa and fungal/yeast isolates by location

	No of isolates				
	Protozoa	Fungi and yeasts			
Location of study	Any	Any	Aspergillus	Candida	Other
Africa					
Ghana	1 (0.7)	82 (54.7)	19 (12.7)	1 (0.7)	62 (41.3)
Accra, Ghana	Unspecified	65 (50.0)	10 (7.7)	1 (0.8)	45 (34.6)
Indian subcontinent					
Nepal	Unspecified	200 (55.9)	75 (20.9)	9 (2.5)	116 (32.4)
Chittagong, Bangladesh	Unspecified	48 (37.8)	24 (18.9)	1 (0.8)	23 (18.1)
Tamil Nadu, India	7 (1.3)	296 (55.0)	76 (14.1)	0 (0)	220 (40.9)
West Bengal. India	4 (0.4)	623 (67.4)	373 (40.3)	7 (0.8)	243 (26.3)
New Delhi, India	Unspecified	13 (20.0)	6 (9.2)	0 (0.0)	7 (10.8)
Madurai, India	3 (0.9)	155 (47.7)	25 (7.7)	Unspecified	116 (35.7)
Hyderabad, India	Unspecified	146 (37.5)	43 (11.1)	2 (0.5)	101 (26.0)
Tamil Nadu, India	33 (1.4)	1176 (49.1)	294 (12.3)	Unspecified	882 (36.8)
Hyderabad, India	3 (2.5)	22 (18.5)	5 (4.2)	1 (0.8)	16 (13.4)
Delhi, India	11 (1.5)	358 (49.1)	149 (20.4)	30 (4.1)	179 (24.6)
Riyadh, Saudi Arabia	Unspecified	Unspecified	Unspecified	Unspecified	Unspecified
Baghdad, Iraq	Unspecified	74 (31.4)	42 (17.8)	4 (1.7)	28 (11.9)
South America					
Asuncion, Paraquay	Unspecified	209 (51.9)	37 (9.2)	4 (1.0)	168 (41.7)
Far East					
Taipei, Taiwan	11 (4.4)	34 (13.5)	5 (2.0)	10 (4.0)	19 (7.5)
Taipei, Taiwan	Unspecified	Unspecified	Unspecified	Unspecified	Unspecified
Singapore	Unspecified	29 (36.3)	5 (6.3)	3 (3.8)	21 (26.3)
Singapore	Unspecified	Unspecified	Unspecified	Unspecified	Unspecified
Hong Kong	6 (6.7)	5 (5.6)	Unspecified	1 (1.1)	4 (4.4)
Bangkok, Thailand	3 (2.3)	46 (35.4)	9 (6.9)	2 (1.5)	37 (28.5)
Australasia					
Auckland, New Zealand	Unspecified	7 (5.3)	Unspecified	Unspecified	Unspecified
Christchurch, New Zealand	Unspecified	Unspecified	Unspecified	Unspecified	Unspecified
Adelaide, Australia	Unspecified	7 (5.2)	3 (2.2)	2 (1.5)	2 (1.5)
Victoria, Australia	4 (3.5)	7 (6.1)	Unspecified	1 (0.9)	6 (5.3)
Brisbane, Australia	Unspecified	13 (6.9)	Unspecified	Unspecified	Unspecified
North America and Canada					
Toronto, Canada	Unspecified	Unspecified	Unspecified	Unspecified	Unspecified
Miami, USA	Unspecified	Unspecified	Unspecified	Unspecified	Unspecified
Pittsburgh, USA	Unspecified	Unspecified	Unspecified	Unspecified	Unspecified
Los Angeles, USA	Unspecified	4 (4.9)	Unspecified	Unspecified	4 (4.9)
Texas, USA	4 (3.8)	8 (7.7)	Unspecified	3 (2.9)	Unspecified
Durham, USA	Unspecified	Unspecified	Unspecified	Unspecified	Unspecified
Europe					
Paris, France	Unspecified	Unspecified	Unspecified	Unspecified	Unspecified
Laussanne, Switzerland	Unspecified	Unspecified	Unspecified	Unspecified	Unspecified
Anatolia, Turkey	Unspecified	50 (22.2)	10 (4.4)	15 (6.7)	25 (11.1)
Amsterdam and Rotterdam	Unspecified	2 (1.8)	0 (0.0)	2 (1.8)	0 (0.0)

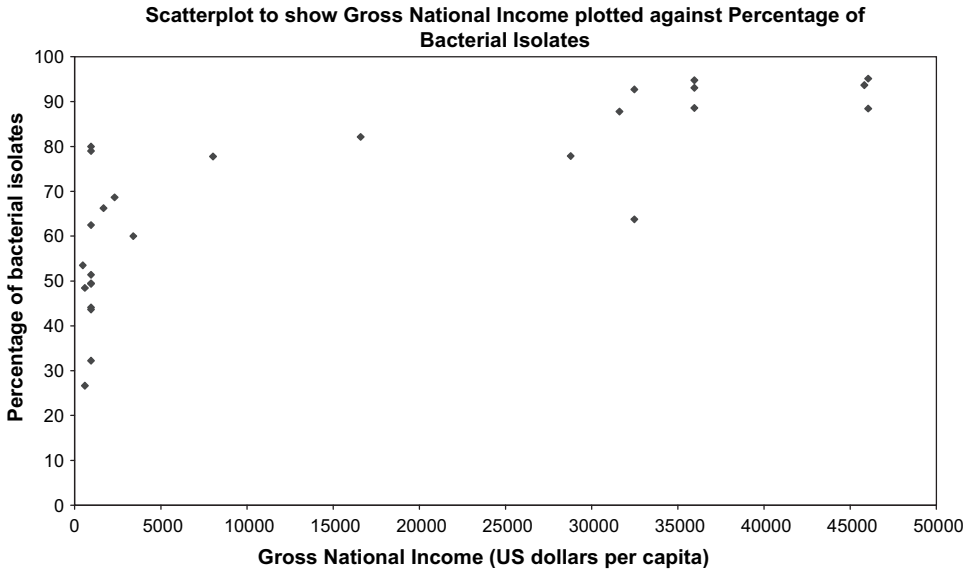

Figure 1 Scatter plot showing the percentage of bacterial isolates in studies not looking exclusively at bacterial causes of microbial keratitis plotted against gross national income (US$ per capita).

patients have to make long journeys to their hospital. Thus, their data may reflect more severe cases of microbial keratitis.

The study from Tamil Nadu[12] found the highest proportion of streptococcus species (46.8%). The authors noted that this figure was only 18.5% in 1986 and suggest that the trend might represent a genuine change in the bacterial flora owing to changes in the climate and environment.

The study from Bangkok[27] had the highest proportion of pseudomonas infections (55%). Interestingly, this study did not have the highest proportion of contact-lens wearers (only 24%). Other studies reported far higher proportions of contact-lens wearers—for example, 44% in a study from Taiwan[23] and 50% in the study from Paris.[11] When we compared the percentage of contact-lens wearers with the percentage of pseudomonal infections, the Spearman correlation coefficient was not statistically significant. Interestingly, Cohen *et al*[39] at Wills Eye Hospital reported a decline in contact lens-related ulcers: during 1998 to 1991, contact-lens wear accounted for 44% of all ulcers, but during 1992 to 1995, it accounted for only 30%. The authors speculated that their figures might reflect a reduction in the number of referrals to their unit due to the increased availability of fluoroquinolones in the community.

Trauma was a major risk factor for corneal infection in certain countries. In Paraguay,[22] the percentage of cases with preceding trauma was 48%, in Eastern Nepal,[14] 53%, in Madurai, South India,[4] and 65% and 83% in Eastern India[10] (most commonly from injury by the paddy or its stalk). The authors of this last study noted an increase in keratitis during the harvesting season.

The above studies also addressed the frequency of self-medication prior to presentation at a tertiary referral unit. In the Madurai study, 20% of patients had been to a village healer, and 87% had been started on topical medication, of whom 8% were on topical corticosteroids. In the study from Eastern India, 18% of patients had used medication before coming to the clinic, and in the Paraguay study, the proportion was 83%. Schwab[40] states that in some developing countries, locally produced over-the-counter antibiotics may be cheaper than imported preparations, and this may have an impact on the prompt use of appropriate therapy. Access to these over-the-counter antibiotics is limited, and individuals may be more inclined to go to local healers who are generally well respected but may instil harmful 'traditional' agents such as vegetable extracts, leaves, herbs, human urine or animal products, or perform practices such as thermal cautery.

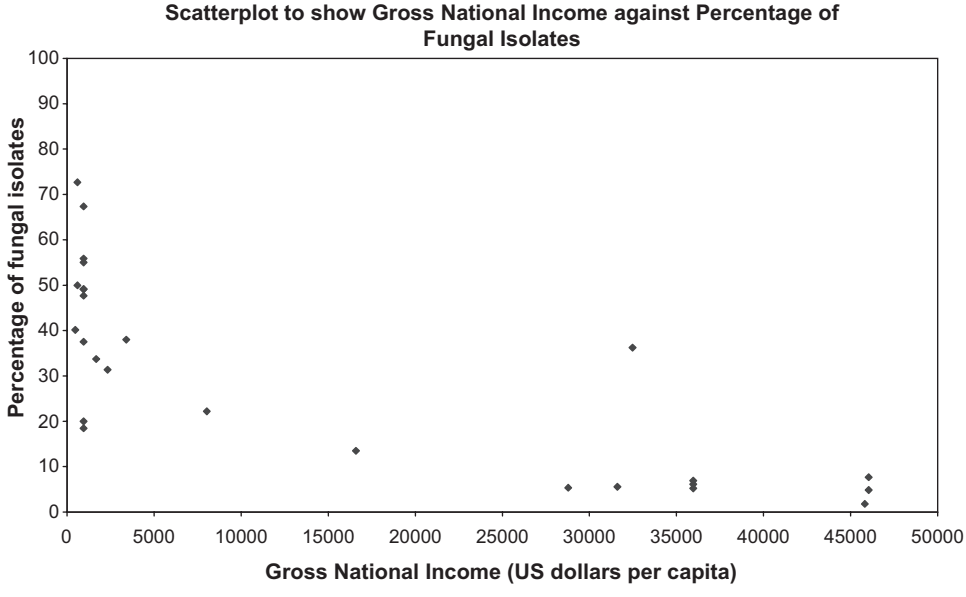

Figure 2 Scatter plot showing the percentage of fungal isolates plotted against gross national income (US$ per capita).

Jeng and McLeod[41] commented on the emerging resistance of bacterial infections to fluoroquinolones. In addition to changes in resistance patterns, studies have also demonstrated changing patterns of causative organisms over time in a given geographical location. Varaprasathan *et al*[42] reported that the proportion of *Streptococcus pneumoniae* and *Pesudomonas aeruginosa* ulcers in Northern California had decreased over a 50-year period, while that of *Serratia marcescens* had increased over the same period. Sun *et al*[43] reported a rise in the percentage of Gram-positive cocci in North China from 25% in 1991 to 70.8% in 1997, as well as a decrease in Gram-negative bacilli from 69% to 23.4% over a similar period.

Leck *et al*[12] have previously compared corneal ulcers in Ghana and South India, while Lam *et al*[5] have discussed differences between Hong Kong, Europe and North America. However, the present study is the first to present a worldwide comparison of corneal infections.

In interpreting this comparison, a number of limitations must be considered. Variations existed in the definition of microbial keratitis between studies. Lam *et al*, reporting on cases from Hong Kong,[5] included patients with 'the clinical presentation of a corneal stromal infiltrate $>1\ mm^2$.' This differs from Srinivasan *et al*,[4] who included patients with 'loss of the corneal epithelium with underlying stromal infiltration and suppuration associated with signs of inflammation with or without hypopyon.' There were variations in methods of culture. For example, one study[16] used sheep's blood agar, chocolate, non-nutrient, Sabauroud, brain–heart infusion and potato dextrose agar, while another[13] used only chocolate and Sabouraud media. Some studies did not specify the media used.[17–19] All studies included bacterial infections, but not all included fungal, protozoal and yeast organisms. The majority of studies looked at all cases of microbial keratitis, while some looked only at patients requiring hospital admission (Wong *et al* and Cheung *et al*[3 30]). It is likely that in these studies, particularly virulent organisms will be over-represented. Finally, data are only available from centres that have conducted studies on microbial keratitis, limiting the coverage of certain regions of the world.

Despite these limitations, we have presented to our knowledge, for the first time, a worldwide overview of causative organisms in microbial keratitis demonstrating associations between specific types of microbial keratitis and national income.

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Geographic variations in microbial keratitis: an analysis of the peer-reviewed literature

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