

CLINICAL SCIENCE

Outcome of corneal transplantation: can a prioritisation system predict outcome?

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Background: In 1995 a prioritisation system for patients waiting for corneal transplantation surgery was adopted in British Columbia. In 1997 a routine outcome assessment programme was adopted. The authors sought to determine the outcomes of corneal transplant surgery in the province of British Columbia and to evaluate if they were associated with waiting list prioritisation.

Methods: Since May 1997 all patients who receive a corneal transplant are enrolled in the Eye Bank of British Columbia (EBBC) outcome assessment programme. Each patient fills out a visual function assessment (VFA) questionnaire before and 12 months after surgery. Data on visual acuity, pain, demographics, and other ocular complications are collected from both patients and surgeons before and after operation.

Results: 269 patients were enrolled in the programme between May 1997 and April 1998. 12 month follow up showed that visual acuity improved in 69.9% of patients, while it remained the same in 20.8%, and got worse in 5.9%. Overall, at follow up 16.6% of patients had intermittent pain and 5.0% had constant pain. 78.6% of patients who experienced intermittent or constant pain before surgery reported no pain at follow up. Visual function improved in 72.4% of patients, remained the same in 4.1%, and worsened in 23.5%. 88% of patients improved in at least one of the three outcome categories. Patients who had the greatest improvement had been assigned the highest priority for surgery. The 11% of patients who did not improve in any of the three categories (visual acuity, pain, or visual function) were more likely to have a preoperative visual acuity better than 20/60, most likely to have old trauma or Fuchs' dystrophy as their primary diagnosis, and to have had fewer points in the EBBC priority scoring system.

Conclusion: The finding that patients who had a high preoperative priority score were more likely to have a good outcome suggests that the priority system was accurately identifying patients at greatest need for surgery. These findings also suggest that outcome from corneal transplant surgery is best measured as a combination of clinical indices and patient derived indices. A routine outcome assessment programme and prioritisation system can assist surgeons and eye banks in better case selection and in anticipating both objective and subjective improvement following surgery.

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Although corneal transplantation has been performed for almost 100 years and is considered a safe and effective procedure, it requires costly tissue preparation and considerable preoperative and postoperative work and expense. Increasingly, patients, governments, and payment agencies are requiring proof that commonly accepted procedures are effective and worthwhile.¹ Waiting lists for procedures of any type are also under close examination and have become political issues in many jurisdictions.

In most eye banks a central patient registry is kept with varying amounts of information on the listed patients. Each surgeon keeps an individual list of their own patients and, when offered tissue, selects patients for surgery from that list. Clearly, those patients in the greatest need should receive tissue first. However, with multiple surgeons this system can break down if there is no overall priority scoring of all patients listed for surgery.

It has become increasingly apparent that easily measured standard Snellen (or equivalent) visual acuities are actually relatively narrow assessments of visual function. Many psychophysical techniques have been developed in the laboratory to obtain a broader picture of what patients can see. Unfortunately most of these techniques are impractical to use in large scale studies outside a single centre. It is easier and perhaps more appropriate to assess visual function (as opposed to acuity) by asking patients to report their ability to perform vision related activities of daily living before and after

surgery. This has been done in the past in the form of interviews and questionnaires but is usually with limited or no preoperative data for comparison and no input from the patients' perspective.²⁻⁶ This is not the objective data, such as Snellen acuity, keratometry, graft clarity, etc, conventionally assessed in outcome studies. However, it may represent a more accurate picture of the patients' ability to function in their environment.

In the corneal transplant outcome assessment programme (a joint effort of the Eye Bank of British Columbia and the British Columbia Centre for Epidemiologic and International Ophthalmology) we have integrated preoperative clinical and visual function information with a postoperative outcome assessment programme that includes clinical and visual function parameters. The Eye Bank of British Columbia (EBBC) maintains a centralised waiting list for the province of British Columbia. All surgeons doing corneal transplant surgery in the province are part of the centralised waiting list. Patient priority is assigned on the basis of surgeon's assessment of specific clinical indices (visual acuity, pain reported by the patient, potential vision in one eye only, and presence of a progressive disease), the patient's assessment of his/her own visual function (as measured by a standardised questionnaire),⁷⁻¹⁰ and the number of months the patient has been waiting for surgery. Information on the development and testing of the priority system has been previously published.⁹ All 17 corneal transplant surgeons in the province participate

Table 1 Preoperative clinical and demographic characteristics

Number	269
Mean age (SD)	66.1 (18.0)
Sex	
Female	56.1%
Male	43.9%
Pain	
None	55.8%
Intermittent	32.7%
Constant	11.5%
Mean VFA (SD)	63.9 (25.3)
Visual acuity	
Operative eye	
≥20/40	7.2%
20/60–20/80	10.6%
20/100–20/200	23.6%
<20/200	58.6%
Other eye	
≥20/40	57.6%
20/60–20/80	16.0%
20/100–20/200	11.1%
<20/200	15.3%
Better eye	
≥20/40	58.2%
20/60–20/80	17.6%
20/100–20/200	16.4%
<20/200	7.8%
Mean months on waiting list (SD)	7.1 (8.5)
Mean priority points (SD)	36.2 (20.9)
Surgeon	
A	5.6%
B	27.9%
C	17.1%
D	11.2%
E	16.0%
All others	22.2%
Diagnosis	
Corneal degeneration	3.0%
Trauma	4.5%
Scar/oedema	8.2%
Fuchs'	12.3%
Keratitis	7.8%
Keratoconus	11.2%
PBK/ABK	39.2%
Regraft	13.4%

Table 2 Improvement in visual acuity (in operative eye)

	Worse VA (n=16)	Same VA (n=56)	Improved VA (n=167)	p Value
Diagnosis				
Corneal degeneration			5 (71.4%)	
Trauma	1 (9.1%)	4 (36.4%)	6 (54.5%)	
Scar/oedema	2 (10.0%)	4 (20.0%)	14 (70.0%)	
Fuchs'	1 (3.6%)	8 (28.6%)	19 (67.9%)	
Keratitis	2 (10.5%)	2 (10.5%)	15 (78.9%)	
Keratoconus	2 (7.1%)	4 (14.3%)	22 (78.6%)	
PBK/ABK	5 (5.3%)	25 (26.3%)	65 (68.4%)	
Regraft	1 (3.3%)	8 (26.7%)	21 (70.0%)	0.390
Preop visual acuity				
≥20/40	10 (7.5%)	33 (24.8%)	90 (67.7%)	
20/60–20/80	4 (9.5%)	3 (7.1%)	35 (83.3%)	
20/100–20/200		8 (20.0%)	32 (80.0%)	
<20/200		8 (53.3%)	7 (46.7%)	0.005
Mean age (SD)	63.1 (23.0)	65.0 (18.4)	66.3 (17.0)	0.751
Sex				
Female	9 (6.5%)	34 (24.6%)	95 (68.8%)	
Male	7 (6.9%)	22 (21.8%)	72 (71.3%)	0.875
Preop pain				
None	14 (10.3%)	30 (22.1%)	92 (67.6%)	
Intermittent	2 (2.5%)	17 (21.5%)	60 (75.9%)	
Constant		9 (37.5%)	15 (62.5%)	0.055
Mean preop VFA (SD)	75.3 (20.2)	58.4 (27.3)	64.9 (23.5)	0.054
Mean priority points (SD)	24.6 (13.2)	42.3 (25.7)	34.8 (17.7)	0.011

in the prioritisation programme. Emergency patients are not included in the programme. Twelve months after surgery, the corneal surgeons completed an outcome assessment form and the BC-EIO distributed visual function questionnaires to surgeons or mailed them directly to patients to complete and return.

As part of the programme, we sought to determine overall outcomes (using multiple measures) and to assess if patients with the best outcomes, as reported by both surgeon and patient, were those who had the highest priority for surgery.

METHODS

From May 1997 to April 1998 inclusive all patients (except emergencies) who received a transplant by one of the 16 participating EBBC surgeons (one surgeon did not participate in the outcome assessment) were enrolled in the routine outcome assessment programme. Once a surgeon decided that an individual required a corneal transplant, the surgeon would fill out a waiting list form; this brief form includes patient demographics, visual acuity in both eyes, primary corneal diagnosis, level of pain, and if the condition is likely to progress. The patient is provided a visual function form (available in English and Chinese; reliability testing completed¹⁰). Twelve months after surgery surgeons are sent a clinical follow up form, which collects postoperative data on visual acuity, complications, other ocular morbidity, and other outcome variables.

Patients are asked to complete a visual function assessment (VFA) questionnaire before and 12 months following their transplant. The preoperative questionnaires are generally filled out in the surgeon's office at the time an individual is added to the corneal transplant waiting list with the EBBC. Postoperative questionnaires are either filled out in the surgeon's office 12 months following surgery or they are mailed to the patient to be returned in a self addressed stamped envelope.

The VFA is a version of the VF-14¹¹ that was revised to be more appropriate to the lifestyles and visual demands of Vancouver's multicultural, multilingual population.⁸ For each question on the VFA there are five choices: no difficulty (4), a little difficulty (3), a moderate amount of difficulty (2), a great deal of difficulty (1), and unable to do the activity (0). An overall score is calculated by taking the average points of all answered items and multiplying by 25; possible scores range from 0 to 100 with 100 being the best possible visual function score.

The best corrected Snellen visual acuity was recorded for each eye at the time that each patient was placed on the waiting list and at their follow up appointment, generally 12 months following surgery. Before surgery, surgeons ask patients if they are experiencing eye pain and this is recorded as either no, sometimes, or constantly. Following surgery a question was added at the end of the VFA questionnaire asking patients if they experience severe eye pain and given the options no, sometimes, or constantly.

The three indices we chose to monitor outcome were visual acuity (operative eye best corrected assessed by surgeon), visual function (assessed by patient via questionnaire), and pain. We considered a patient "preop complete" if all three measures were available preoperatively. Similarly, we considered a patient "postop complete" if all three measures were available postoperatively.

In the analysis patients with completed data were compared with those without complete data; Student's *t* test was used to compare the means of the continuous variables (age, VFA score, priority points, etc) and a χ^2 test was used to

Table 3 Improvement in pain

	Worse pain (n=26)	Same pain (n=92)	Improved pain (n=62)	p Value
Diagnosis				
Corneal degeneration	1 (16.7%)	4 (66.7%)	1 (16.7%)	
Trauma	2 (28.6%)	2 (28.6%)	3 (42.9%)	
Scar/oedema	3 (23.1%)	10 (76.9%)		
Fuchs'	3 (11.1%)	15 (55.6%)	9 (33.3%)	
Keratitis	3 (18.8%)	12 (75.0%)	1 (6.3%)	
Keratoconus	2 (13.3%)	12 (80.0%)	1 (6.7%)	
PBK/ABK	8 (11.6%)	26 (37.7%)	35 (50.7%)	
Regraft	4 (14.8%)	11 (40.7%)	12 (44.4%)	0.006
Preop visual acuity (best corrected)				
≥20/40	13 (13.7%)	44 (46.3%)	38 (40.0%)	
20/60–20/80		23 (69.7%)	10 (30.3%)	
20/100–20/200	7 (22.6%)	15 (48.4%)	9 (29.0%)	
<20/200	5 (45.5%)	4 (36.4%)	2 (18.2%)	0.005
Postop visual acuity (best corrected)				
≥20/40	13 (10.5%)	66 (53.2%)	45 (36.3%)	
20/60–20/80	4 (22.2%)	8 (44.4%)	6 (33.3%)	
20/100–20/200	2 (18.2%)	8 (72.7%)	1 (9.1%)	
<20/200	4 (50.0%)	3 (37.5%)	1 (12.5%)	0.029
Mean age (SD)	61.6 (17.7)	66.2 (16.2)	74.2 (12.5)	0.002
Sex				
Female	22 (19.8%)	49 (44.1%)	40 (36.0%)	
Male	5 (7.1%)	43 (61.4%)	22 (31.4%)	0.025
Preop pain				
None	22 (21.0%)	83 (79.0%)		
Intermittent	5 (8.8%)	8 (14.0%)	44 (77.2%)	
Constant		1 (5.3%)	18 (94.7%)	<0.001
Mean preop VFA (SD)	50.1 (21.6)	67.0 (24.2)	65.2 (26.6)	0.018
Mean priority points (SD)	37.6 (19.7)	25.8 (16.0)	51.0 (20.7)	<0.001

compare proportions in the categorical data (pain, visual acuity, sex, etc). For each of the three improvement indices patients were classified at worse, same, and improved and these categories were compared in terms of the clinical and demographic factors. Next, patients were classified by the number of categories they improved in 0, 1, 2, or 3 and the

clinical and demographic factors were compared between these categories.

RESULTS

In the 12 month period of enrolment, the 269 patients who had a corneal transplants were either on the existing waiting

Table 4 Improvement in visual function assessment

	Worse VFA (n=40)	Same VFA (n=7)	Improved VFA (n=123)	p Value*
Diagnosis				
Corneal degeneration	1 (14.3%)		6 (85.7%)	
Trauma	2 (28.6%)		5 (71.4%)	
Scar/oedema	2 (15.4%)		11 (84.6%)	
Fuchs'	8 (29.6%)	1 (3.7%)	18 (66.7%)	
Keratitis	2 (13.3%)	2 (13.3%)	11 (73.3%)	
Keratoconus	4 (23.5%)		13 (76.5%)	
PBK/ABK	15 (24.6%)	3 (4.9%)	43 (70.5%)	
Regraft	5 (22.7%)	1 (4.5%)	18 (72.2%)	0.915
Preop visual acuity (best corrected)				
≥20/40	22 (23.4%)	6 (6.4%)	66 (70.2%)	
20/60–20/80	6 (20.0%)		24 (80.0%)	
20/100–20/200	5 (17.9%)	1 (3.6%)	22 (78.6%)	
<20/200	2 (25.0%)		6 (75.0%)	0.761
Postop visual acuity (best corrected)				
≥20/40	27 (22.7%)	5 (4.2%)	87 (73.1%)	
20/60–20/80	4 (23.5%)		13 (76.5%)	
20/100–20/200			8 (100.0%)	
<20/200	4 (50.0%)	1 (12.5%)	3 (37.5%)	0.169
Mean age (SD)	68.5 (15.6)	68.8 (17.7)	66.8 (17.4)	0.849
Sex				
Female	21 (20.2%)	4 (3.8%)	79 (76.0%)	
Male	19 (28.8%)	3 (4.5%)	44 (66.7%)	0.407
Preop pain				
None	22 (22.2%)	4 (4.0%)	73 (73.7%)	
Intermittent	12 (23.5%)	3 (5.9%)	36 (70.6%)	
Constant	6 (30.0%)		14 (70.0%)	0.79
Mean preop VFA (SD)	67.5 (24.1)	88.0 (15.8)	61.7 (24.6)	0.014
Mean priority points (SD)	39.1 (24.0)	20.8 (9.4)	36.4 (21.1)	0.123

*Significance levels were calculated (*t* test) by comparing the patients who improved with those that did not.

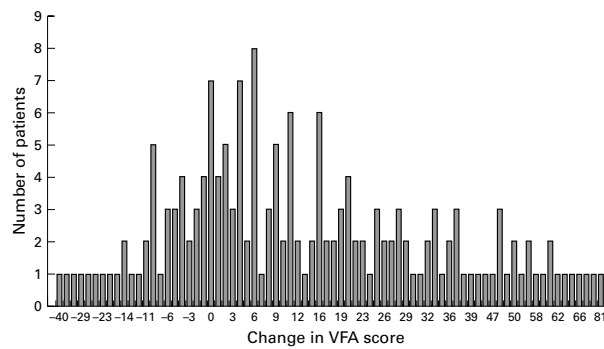


Figure 1 Change in VFA following transplant.

list (n = 126) at the start of the period or were placed on the waiting list during the period (n = 143). During this period, an additional 26 patients had corneal transplantation surgery on an emergency basis; this group is not reflected in our findings. Among 269 potential enrolled patients 216 (80.3%) have complete preoperative information. Preoperative clinical and demographic findings of the population under study are shown in Table 1. A comparison of the patients who had complete information with those who did not revealed that there were no differences in these two groups in terms of age, sex, pain, visual function, or visual acuity (data not shown).

Complete postoperative information was achieved on 159 patients (59.1% of our total 269 and 63.0% (136/216) of our 216 with complete preoperative information). Patients without a complete postoperative history did not differ from those with complete information in terms of age, pain, or visual function. Males were slightly more likely to not have a complete follow up. The only factor associated with completeness was the surgeon; some surgeons failed to provide complete information on all patients (data not shown). Since

there was no significant difference between the two groups, we used findings from all 269 patients.

Visual acuity

At the 12 month follow up, 69.9% of patients demonstrated improvement in visual acuity (operative eye), moving from one visual acuity category to one or more categories better, while 20.8% of patients remained the same. In 5.9% of patients the vision in the operative eye decreased (Table 2). Among the operative eye blind (<20/200) patients 27.2% remained blind following surgery. Among the 17 patients who had good vision (>20/60) in their operative eye before surgery 10 (58.8%) retained good vision at 12 months. Among the remaining seven patients, five eyes were blind at 12 months. Improvement in visual acuity was not evenly distributed among the diagnosis groups; patients with old trauma and Fuchs' dystrophy showed the least improvement.

Pain

Constant pain was reported by 11.5% of patients before surgery, and intermittent pain was reported by 32.7%. Following surgery 5.0% of patients still reported constant pain and 16.6% reported intermittent pain. Among the patients reporting either constant or intermittent pain before surgery 77.6% reported no pain at follow up. However, among the 105 patients who did not report pain before surgery 21.0% reported either constant (2.9%) or intermittent (18.1%) pain at follow up. Improvement in pain was more likely among aphakic and pseudophakic bullous keratopathy (ABK/PBK) cases (Table 3).

Visual function

There was a wide range (4–100) in reported visual function prior to surgery. The mean value was 63.9 (SD 25.3), median 66.0. Following surgery 72.4% of patients showed an improvement in visual function while 4.1% of patients remained the

Table 5 Number of outcome categories improved in

	None (n=16)	1 Improved (n=65)	2 Improved (n=47)	3 Improved (n=8)	
Mean age (SD)	66.4 (16.1)	64.4 (17.7)	70.9 (14.5)	79.0 (2.6)	0.103
Sex					
Female	6 (6.7%)	46 (51.7%)	31 (34.8%)	6 (6.7%)	
Male	10 (21.3%)	19 (40.4%)	16 (34.0%)	2 (4.3%)	0.083
Diagnosis					
Corneal degen	1 (16.7%)	3 (50.0%)	2 (33.3%)		
Trauma		2 (40.0%)	3 (60.0%)		
Scar/oedema		7 (70.0%)	3 (30.0%)		
Fuchs'	3 (15.8%)	8 (42.1%)	7 (36.8%)	1 (5.3%)	
Keratitis	1 (7.7%)	10 (76.9%)	2 (15.4%)		
Keratoconus	2 (13.3%)	10 (66.7%)	2 (13.3%)	1 (6.7%)	
PBK/ABK	5 (10.2%)	20 (40.8%)	19 (38.8%)	5 (10.2%)	
Regraft	4 (21.1%)	5 (26.3%)	9 (47.4%)	1 (5.3%)	0.524
Preop visual acuity (best eye)					
≥20/40	13 (15.3%)	44 (53.7%)	25 (30.5%)		
20/60–20/80	2 (8.0%)	8 (32.0%)	12 (48.0%)	3 (12.0%)	
20/100–20/200		10 (41.7%)	9 (37.5%)	5 (20.8%)	
<20/200	1 (20.0%)	3 (60.0%)	1 (20.0%)	0 (0.0%)	0.003
Preop pain					
None	13 (16.7%)	51 (65.4%)	14 (17.9%)		
Intermittent	2 (4.7%)	10 (23.3%)	27 (60.5%)	5 (11.6%)	
Constant	1 (6.7%)	4 (26.7%)	7 (46.7%)	3 (20.0%)	<0.001
Mean preop VFA (SD)	74.4 (23.1)	64.8 (26.1)	63.9 (20.4)	48.4 (23.5)	0.095
Mean priority points	24.9 (20.5)	30.1 (20.8)	42.7 (14.8)	63.1 (15.6)	<0.001
Mean months waited	9.2 (11.3)	8.4 (10.1)	7.9 (9.5)	1.9 (1.1)	0.336
Surgeon					
A	1 (6.3%)	7 (43.8%)	7 (43.8%)	1 (6.3%)	
B	5 (12.2%)	15 (36.6%)	16 (39.0%)	5 (12.2%)	
C	4 (13.8%)	16 (55.2%)	9 (31.0%)		
D	1 (8.3%)	7 (58.3%)	4 (33.3%)		
E	2 (10.0%)	12 (60.0%)	6 (30.0%)		
F	3 (14.3%)	8 (38.1%)	7 (33.3%)	3 (14.3%)	0.644

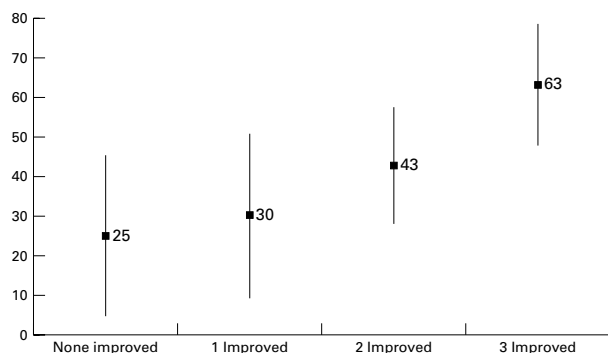


Figure 2 Mean preoperative priority points ($p < 0.001$).

same and in 23.5% visual function was reduced (Table 4). Patients with the poorest preoperative visual function had the best improvement in visual function at the 12 month follow up (Pearson's $r = -0.53$, $p < 0.001$) The range of improvement in VFA is shown in Figure 1.

Outcome

According to our criteria, a good outcome was defined as improvement in one of three indicators: visual acuity (operative eye), pain, and visual function (person). According to these criteria 88.2% of patients improved in a least one of these categories (Table 5). Patients demonstrating the best improvement had aphakic or pseudophakic bullous keratopathy while the worst improvement was found among patients with a history of Fuchs' dystrophy. Overall, there was a significant association between outcome and priority scores before surgery (Fig 2).

DISCUSSION

Our prioritisation system is based on the assumption that patients who can achieve the best improvement should be those who should receive the highest priority for surgery. Accordingly, analysis of our priority system showed that, indeed, patients who improved the most, in fact, did have the highest priority scores.

This project was carried out as a pilot for a routine corneal transplant outcome assessment programme. The difficulty in obtaining complete preoperative and postoperative data was expected and the fact that complete preoperative data collection is more common among some ophthalmologists versus others is also not unexpected. We chose to include all available data to represent corneal transplant surgery in the province.

As the results show, corneal transplantation is a safe and effective procedure as measured by multiple indicators of success. When measured in a prospective fashion a clear majority of patients improved, not just in measured acuity but in pain control and their ability to function visually. Since quality of life is the major indicator of success from the patient's perspective, visual acuity may not be the most appropriate outcome measure if used in isolation. Visual function assessment provides a far more in-depth and intuitive measure of a patient's ability to function particularly when combined with visual acuity. It encompasses patients' ability to interact with their surroundings and perform their daily activities. As expected, results varied with the underlying diagnosis and preoperative best corrected acuity.

Significantly, patients with higher priority scores showed more improvement than those of lower priority. A certain amount of variation is to be expected since corneal disease can be progressive in one or both eyes. Over a long waiting period some patients will acquire a higher priority as their condition worsens and this will not necessarily be captured in the waiting list data. However, it was interesting to note that patients who had the best outcome ended up waiting the shortest amount of time. Other factors not predicted by our programme may change the priority score; these include spontaneous improvement (rare), new uncontrolled systemic illness (increasing surgical risk and making transplantation temporarily inadvisable), and patient unavailability. Individual surgeons will sometimes reshuffle their patient priorities and operate on these increased or decreased priority patients sooner or later than would be predicted by the central list. These factors are probably responsible for the variability noted. Overall however, the priority system appears to deliver what patients, governments, and payment agencies expect: those in greatest need receive appropriate, effective treatment based on fair, standardised, reproducible criteria.

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