

The cost-effectiveness of technology transfer using telemedicine

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The high burden of disease in developing countries often makes it difficult for health systems in these countries to attain the same level of specialist skills as industrialized countries. Technology transfer is one way to improve specialist skills whilst at the same time reducing the burden of disease. This paper describes the use of teleophthalmology, a form of telemedicine, as a mode of technology transfer between the United Kingdom and South Africa. As the burden of eye disease in South Africa is high, the country cannot afford the level of ophthalmic specialization achieved in the UK. The paper estimates the cost-effectiveness of the technology transfer project in terms of a cost per Disability Adjusted Life Year (DALY) averted. We found the technology transfer project to be cost-effective in reducing the burden of eye disease, and that practitioners in South Africa also learned novel procedures that could help future patients and improve cost-effectiveness. Technology transfer using telemedicine is a cost-effective method that richer countries can employ to aid capacity building in the health care systems of poorer countries.

Key words: telemedicine, teleophthalmology, technology transfer, costs, DALY, South Africa

Introduction

All health services require a skilled workforce in order to deliver effective health care, but it is often difficult for health systems in developing countries to attain the same level of specialist skills as industrialized countries. This arises because the high level of disease burden in poorer countries compounds the problem of sustaining adequate health care systems from their limited resources. Yet there has been only a limited response by the international community to the high disease burdens in developing countries, and investment by richer countries in poorer countries has been inadequate (Sachs 2001).

One way that richer countries could support the health care systems of poorer countries is by assisting in building the scientific capacity in those countries (Harris and Tanner 2000). Health technology transfer is one method of building capacity: specialist skills are imparted to local practitioners who can then provide benefits that will improve the health of the local population (Donald 1999). One mode of technology transfer, as yet unevaluated, is to use telemedicine as a form of communication and learning between practitioners in richer and poorer countries.

This paper describes the use of teleophthalmology as a mode of technology transfer between the United Kingdom (UK) and South Africa. The burden of eye disease in South Africa is high, with blindness approximately five times higher than it is in the UK. As a result, there is a high demand for ophthalmic services in South Africa; yet the country cannot afford the level of ophthalmic specialization achieved in the UK. The aim of the paper is to report the costs and benefits to patients and practitioners associated with the technology transfer project.

Methods

Model of technology transfer

The conceptual framework of technology transfer used is based on that developed by Bozeman (2000). This framework identifies the following as key components of technology transfer: the transfer agent, transfer media, transfer object and transfer recipient.

The transfer agent was Moorfields Eye Hospital, London, UK. The hospital has approximately 70 inpatient beds (including hostel beds) and serves the local community and patients around the UK as a tertiary service, providing a full spectrum of ophthalmic subspecialties including glaucoma, adnexal, strabismus, corneas and vitreo-retinal. Around 18 000 operations are performed annually, with approximately 250 000 outpatient attendances per year. Ophthalmologists at Moorfields Eye Hospital provided specialist advice as part of the technology transfer project. These included ophthalmologists-in-training and consultant ophthalmologists who all have expertise in treating diseases of the cornea, retina and anterior segment, as well as glaucoma, oculoplastics, neuro-ophthalmology, uveitis and ocular motility.

The transfer medium was teleophthalmology, the practice of eye medicine at a distance. Videoconferencing was used in conjunction with the transmission of slit-lamp images of the eye. Videoconferencing facilities were installed at Moorfields hospital in London and at the recipient hospital in South Africa. A slit lamp and a hand-held camera were also purchased for the recipient hospital in South Africa.

The transfer object was specialist advice on clinical

management. Videoconferencing sessions were held every week, lasting between 1–2 hours, with three to four cases discussed. Specialist advice was provided on patient diagnosis, management and treatment. Responsibility for clinical decision-making following the consultation remained with the practitioner in South Africa.

The transfer recipients were patients and ophthalmologists at Edendale Hospital, a district hospital near Pietermaritzberg, the provincial capital of KwaZulu-Natal in South Africa. Patients attending the hospital are primarily of Zulu origin. The hospital has 1225 inpatient beds, of which 38 are based in the eye department. The hospital also has an outpatient eye clinic that treats a high number of patients, around 15 000, per year. The types of cases presenting at the eye clinic are largely anterior segment, external eye disease and multiple pathology. An expert in telemedicine from the UK trained the local practitioners in the use of the teleophthalmology equipment.

The technology transfer project ran for 12 months and an evaluation was conducted alongside the project.

Evaluation

Design

Evaluations of technology transfer projects are rare (Bozeman 2000) and consequently there is a lack of literature on evaluation methods. An estimate of the benefits of the technology transfer is required, however, in order to determine whether the benefits justify the costs. Even in the field of telemedicine, there is no general agreement as to how to evaluate its costs and benefits (Hailey et al. 1999). Particular methodological issues include how to estimate costs averted as a result of telemedicine and the role of patient-based outcome measures (McIntosh and Cairns 1997). Furthermore, a recent systematic review found there to be no good evidence that telemedicine is cost-effective (Whitten et al. 2003). This arises because studies erroneously draw conclusions about cost-effectiveness based solely on evidence of apparent costs savings (Whitten et al. 2003). There are no economic evaluations of teleophthalmology, although there is one costing analysis (Lamminen et al. 2001), and there are no evaluations of the role of telemedicine in developing countries (Roine et al. 2001). Nevertheless, the potential of telemedicine within developing countries has been recognised (Edworthy 2001).

An important aspect of any economic evaluation is finding a design that can attribute costs and benefits to the intervention being evaluated. Randomized controlled trials are often seen as the gold standard to determine attribution but have rarely been used in telemedicine, although this is beginning to change (Wootton et al. 2000; Wallace et al. 2002). In this study, randomization of patients to receive teleophthalmology was not ethical since the control group would be denied specialist advice from the UK, and that advice may have led to better patient outcomes than standard care. Instead, consensus methods were used to determine attribution to teleophthalmology. Consensus methods are valid data collection methods

(Wortman et al. 1998) that are increasingly being used in health services research (Vella et al. 2000) and as sources of information about resource use for economic evaluations (Evans 1997). The consensus method used has been described in detail elsewhere (Taylor et al. 2003).

Briefly, the consensus process was conducted at the end of the technology transfer project and involved ophthalmologists reviewing the case notes of patients who had received teleophthalmology. The consensus method judged whether costs (clinical examinations, tests, investigations and inpatient admissions) and benefits (visual acuity) were attributable to teleophthalmology. It also judged whether any procedures recommended by the London-based specialist were novel. The results of the consensus process were recorded as definitely related, possible related or not related to teleophthalmology. The findings of the consensus process were then used as the basis for estimating costs and benefits.

Costs

Costs included the set-up and running costs of teleophthalmology, as well as the changes in costs attributable to teleophthalmology in terms of clinical examinations, tests, investigations and inpatient admissions.

The set-up costs included: equipment (videoconferencing, slit lamps, cameras, video recorders, cabling and maintenance); installation of telecommunication (ISDN) lines in London and Edendale; and training costs. The equipment costs were based on prices paid in the UK. The installation costs were based on charges paid. The training costs included the costs of using the ISDN lines, staff costs of installers and trainers and the travel costs of the trainer from the UK. The ISDN costs for training were based on actual time spent training and were costed at the charged rate. The staff time involved in training was 160 hours at Edendale. Staff time involved in training in London via the video link was 175 hours and this was costed based on staff cost per hour.

The running costs comprised the staff costs of those involved in the consultation in London and in South Africa, and the telecommunication costs associated with each teleconsultation. The staff involved in each teleconsultation and the duration of each teleconsultation were recorded at the time of each session. Staff costs in London were based on cost per hour of the staff involved, as were the staff costs in South Africa. The telecommunication costs (ISDN usage) were costed at the charged rate.

Clinical examination, test and investigation costs attributable to teleophthalmology were identified from the consensus process. These were the difference between the cost of additional clinical examinations, tests and investigations and the savings in cost as a result of avoided clinical examinations, tests and investigations. Tests and investigations were costed using local unit costs.

Inpatient admission costs attributable to the teleophthalmology were identified from the consensus process and were the difference between the costs of admissions added and the

savings from costs of admissions avoided. Admission costs were costed based on the length of stay of each admission (from the inpatient ward records) and the average cost per hospital day from the local hospital.

All costs are presented in UK pounds sterling, in 2000 prices. Costs in South African Rand were converted to UK pounds using exchange rates at the time of the project (£1 = 10.04 Rand in November 2001). Patient-specific costs were estimated and the set-up costs were divided by the number of patients to give an average set-up cost per patient.

Cost-effectiveness

Cost-effectiveness was measured in terms of cost per Disability Adjusted Life Year (DALY) averted. DALYs measure burden of disease in terms of both premature death and disability (World Bank 1993; Murray 1994; Murray and Lopez 1997). DALYs are the sum of the present value of future years of lifetime lost through premature mortality (years of life lost, YLLs) and the present value of future lifetime adjusted for the average severity of disability caused by the disease (years of life lived with disability, YLDs). The formula for calculating DALYs is presented in Murray (1994) and the methods used here follow the recommended methodology by Fox-Rushby and Hanson (2001, p. 327). Estimates of YLLs and YLDs took the same form: $YLLs(r, K, B)$ where r is the discount rate (0.03), K is the age weighting (1) and B is the parameter from the age weighting function (0.04).

The DALYs averted by teleophthalmology were estimated based on the changes in visual acuity identified from the consensus process. Only those patients where teleophthalmology had definitely or possibly led to an improvement in visual health, as measured by an improvement in visual acuity, were included. DALYs were then estimated for each patient and summed across patients.

In order to estimate YLDs, information on age of onset of disability, duration of disability and the disability weight without treatment was required. Age of onset was equivalent to the age of the patient when they presented at the eye clinic. The duration of the disability was classified into temporary (1 year) or chronic (10 years) as part of the consensus process. The disability weight was estimated by converting the measure of visual acuity before teleophthalmology into a utility (a measure between zero and one, where one is good health). An equation converting visual acuities into utility was used to estimate utilities (Sharma et al. 2000). Since a high utility score reflects good health rather than disability, the utility score was inverted in order to estimate a disability weight.

In order to estimate YLLs, two steps were required. The first step estimated YLLs from the age of death based on information on the age of death without treatment and the life expectancy at age of death. Age of death without treatment was the age of onset plus the duration of the disability. Life expectancy at the age of death was derived from age-sex specific life tables for South Africa (US Bureau of the Census

2002). The second step then converted the value from step one to the expectation of life lost at age of onset in order that each patient-specific DALY estimate was calculated from the same time point, that is, age of onset (Fox-Rushby and Hanson 2001).

The YLDs and YLLs were summed to give a DALY per patient and were aggregated across patients. In order to estimate DALYs averted, the YLD formula was used and the disability weight of the treated state was substituted for the disability weight of the untreated state. The disability weight for the treated state was estimated by converting the visual acuity after teleophthalmology into a utility using the method described above. This figure was then subtracted from the number of DALYs to give the number of DALYs averted. DALYs were discounted at 3% and used a parameter for age weighting 0.04 (Murray and Lopez 1997). The method of presentation follows Fox-Rushby and Hanson (2001).

The number of DALYs averted as a result of teleophthalmology was combined with cost information to estimate a cost per DALY averted. Sensitivity analysis on cost per DALY estimates was performed to address uncertainty in the estimates. The sensitivity analysis focused on the key uncertainties – the duration of the disability and the number of patients whose benefits were directly attributable to teleophthalmology. The base case duration estimate was 10 years and, in the absence of any other evidence, this was varied over a wide range of 5 years and 20 years. The eligibility of patients included was also changed from the base case of those who had definite or possible improvements to those who had definitely improved.

Practitioner benefits

Practitioner benefits were also estimated but could not be included in the cost-effectiveness ratio. Although these benefits are hard to quantify, the measures adopted addressed satisfaction as well as learning. The significance of the learning benefit is that learning should lead to improved patient health benefits for future patients. Four measures of practitioner benefit were estimated. The first was a measure of practitioner satisfaction with the quality of images produced. This was determined by the practitioner's own ability to capture still images using a slit lamp rather than capturing real-time images. The second measure was practitioner comfort with the process. These two measures were estimated by asking practitioners to complete a data collection form at the end of each teleconsultation.

The third measure of practitioner benefit was a measure of the reason for seeking specialist advice. This could be either consultant proxy (i.e. the advice from practitioners at Moorfields substituted for lack of available consultant advice in South Africa) or second opinion (i.e. the advice was sought to confer a second opinion in difficult cases). The final measure was an estimate of the impact on medical education. This was defined as the novel procedures learned through the technology transfer process; novel procedures were those that would not have been usual practice by the local

practitioners. These two measures were estimated from the consensus process.

Results

Number and age of patients

Over the 12-month period from 1 May 2000 to 30 April 2001, 113 patients were referred to teleophthalmology at Edendale hospital. Of these, case notes with follow-up information were available for 90 patients and the notes of these patients were to inform the consensus process. The average age of the 90 patients was 26 years.

Costs

Table 1 reports the set-up costs of teleophthalmology. The total set-up cost was £13 445 at Edendale hospital and £13 933 at Moorfields Hospital. The average total set-up cost per patient was £242.

The running costs were £91 per patient, of which 52% was accounted for by the staff costs in London and 47% was accounted for by telecommunications costs.

Figure 1 shows the average cost per patient of clinical examinations, tests, investigations and admissions added, as well as those saved as a result of teleophthalmology. It shows that there were no savings in the costs of clinical examinations, tests or investigations, but there was a slight saving in the inpatient costs. This saving was not enough to offset the

other increases in cost, and therefore, overall, teleophthalmology increased the costs of clinical examinations, tests, investigations and admissions by an average of £26 per patient.

The teleophthalmology project was cost-increasing with an average cost per patient of £359 (£242 for set-up costs, £91 for running costs, and £26 for the costs of clinical examinations, tests, investigations and admissions). Clearly, not all of the additional average total cost is incurred by Edendale hospital, since the set-up costs are incurred by Moorfields hospital. Furthermore, the only element of the £91 consultation cost incurred by the district hospital is local staff costs (£1 of the £91 consultation cost). Edendale hospital does, however, incur the increased clinical examination, tests, investigations and inpatient admission costs (£26 per patient).

Cost-effectiveness

The number of patients who had improved visual acuity was 57 (63%). Table 2 shows that the DALYs averted by teleophthalmology were 10.4 (for the 57 patients who had improved visual acuity). When the total DALYs are averaged across the 90 patients, the average DALYs averted were 6.8. When the additional costs of £359 are divided by the DALYs averted of 6.8, the cost per DALY averted is £53.

Table 3 shows the results of the sensitivity analysis on DALY calculations that alter duration and patients included. Increasing the duration leads to fewer DALYs averted and

Table 1. Set-up costs of teleophthalmology

Cost type	Edendale Hospital, SA £	Moorfields Hospital, UK £	Total £
Equipment			
Videoconference equipment ^a	3 328	3 328	6 655
Slit lamps ^b	1 270	0	1 270
Hand held camera	1 973	0	1 973
Video recorder	0	2 454	2 454
Cabling	552	552	1 104
Maintenance of video conference equipment	250	250	500
Installation			
ISDN installation ^c	154	600	754
ISDN rental	670	2 160	2 830
Training			
Staff	476	0	476
ISDN usage for training ^d	1 033	2 140	3 173
Staff ^e	2 240	2 450	4 690
Travel costs to South Africa	650	0	650
Subsistence	850	0	850
Total	13 445	13 933	27 373
Average set up cost per consultation^f	115	123	242

^a Equivalent annual cost annuitized at 6% over 5 year life span (cost of £14 017).

^b Equivalent annual cost annuitized at 6% over 20 year life span (cost of £14 568).

^c The installation costs were £51 per installation in South Africa and £200 per installation in the UK.

^d ISDN usage was charged at a rate of 41 pence per minute per line.

^e All staff training was costed at £14 per hour.

^f Based on 113 consultations.

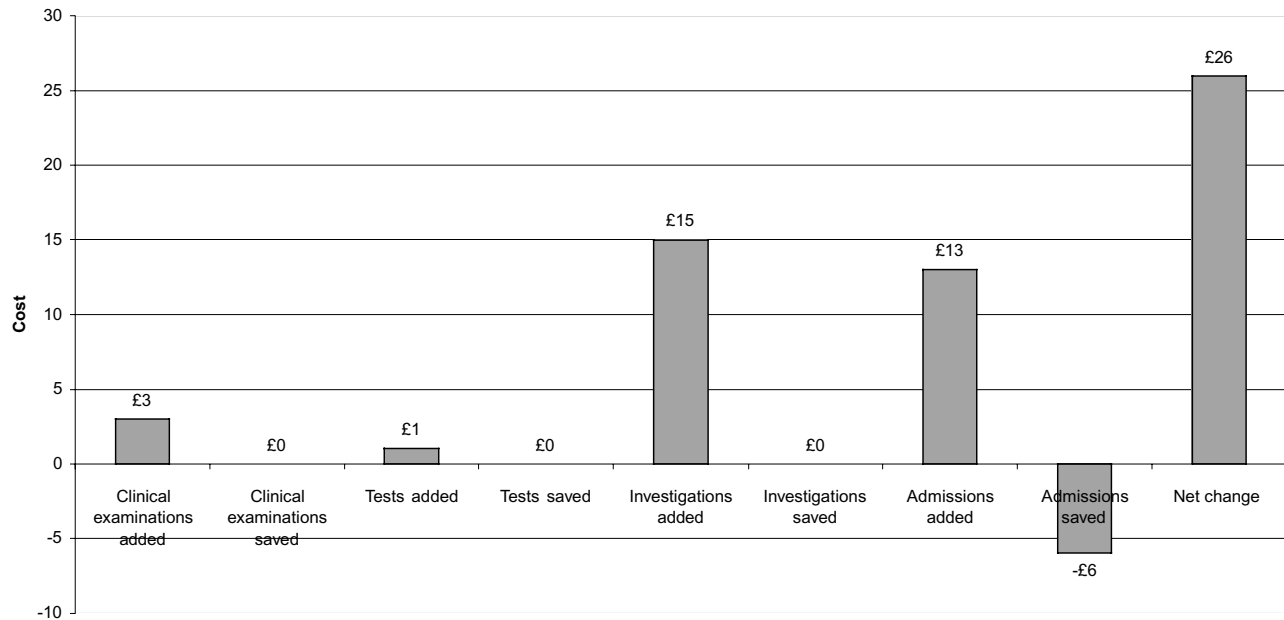


Figure 1. Average cost of clinical examinations, tests, investigations and admissions added and saved

Table 2. Data inputs and results of DALY calculation

Data inputs	Benefit in absence of teleophthalmology ^a	Benefit from teleophthalmology
Mean age of death (years)	41.1	64.9
Mean life expectancy at age of death (years)	27.3	n.a.
Discount rate	0.03	0.03
Age weighting	0.04	0.04
Mean disability weight	0.45	0.36
Mean age of onset (years)	31.1	31.1
Duration of disability (years)	10	10
Type of DALY used	Murray 1996	Murray 1996
DALYs [0.03,1,0.04]		
YLLs	14.4	0
YLDs	4.0	7.9 (5.0)
DALYS averted [0.03,1,0.04] ^b	10.4	n.a.
<i>Averaged across 57 patients</i>		
DALYS averted [0.03,1,0.04] ^c	6.8	n.a.
<i>Averaged across 90 patients^c</i>		

^a Situation if patient did not have teleophthalmology and disability and age of death were unaffected.

^b $14.4 + 4.0 + 7.9 = 10.4$.

^c Including those 33 patients who did not have their visual health improved by teleophthalmology.

to a higher cost per DALY averted. Changing the eligibility of patients included from the base case (those with definite or possible improvements in visual health) to only those with definite improvements reduces the DALYs averted and increases the cost per DALY averted to £449.

In 41% of cases, practitioners perceived the quality of the images to be high, and in 49% of cases, practitioners reported high comfort with the process. In 72% of cases, the reason for local practitioners seeking specialist advice was that a consultant was not available locally. There were 10 novel procedures identified during the technology transfer process, as shown in Table 4.

Discussion

This paper has reported on the cost-effectiveness and practitioner benefits associated with a technology transfer project using teleophthalmology to provide specialist advice to practitioners in South Africa. The set-up costs were the largest proportion of the total costs, but at a total set-up cost of around £27 000 this can be seen as a modest investment for an industrialized country to make in the health care system of a developing country. The recipient hospital in South Africa had to devote staff costs as well as incur the costs of increased clinical examinations, tests, investigations and inpatient admissions arising from teleophthalmology. Had

Table 3. One-way sensitivity analyses on DALY and cost per DALY calculations

Assumption	DALYs averted	Cost per DALY averted
Base case	6.8	£53
Change duration of disability from 10 years to 5 years	8.1	£44
Change duration of disability from 10 years to 20 years	4.9	£73
Include only cases where improvement in visual health is definitely attributable to teleophthalmology	0.8	£449

Table 4. List of novel procedures

Procedure	Details
(1) Use of chemotherapy and radiation	The use of chemotherapy and radiation was advised for the treatment of a tumour advocating that the combined use of the two treatments was more effective.
(2) Use of Mitomycin with excision	The use of Mitomycin C applied topically immediately post-operatively was advised for the treatment of squamous cell carcinomas of the conjunctiva.
(3) Beta plaque	The use of beta plaque for pterygium was advised to prevent recurrence.
(4) Avoidance of cryotherapy	The use of cryotherapy for the treatment of diabetic retinopathy was not advised as it causes increased vessel leakage.
(5) No evidence of help and prophylactic antibiotics	The use of prophylactic antibiotics to prevent recurrent ocular infection (corneal) was not advised as they do not prevent infections.
(6) Use of excimer discussed	The use of the excimer laser for the treatment of superficial corneal disease was discussed as a possible treatment option.
(7) Disinfection of corneal tonometer	The use of hypochlorite solution to disinfect tonometer heads was advised as it is an effective way to prevent iatrogenic spread of conjunctivitis.
(8) Construction of conjunctival shield	The construction of a conjunctival shield was advised by modifying existing ocular shells.
(9) Diamox post trabeculectomy surgery	The use of Diamox immediately post trabeculectomy surgery was not advised in the management of too high and too low intra ocular pressure (IOP) as it is an aqueous suppressant.
(10) Stem cell graft	The concept of replacing stem cells in patients with stem cell deficiency was advised as a treatment option.

the number of patients who received teleophthalmology been higher, the set-up costs would have been spread across a higher volume resulting in lower average costs.

Although the technology transfer project was cost-increasing, it led to patient benefits (as measured by DALYs) and therefore to a reduction in the burden of eye disease. The low average age of patients meant that the number of DALYs averted was high. If this age is representative of the population of the eye clinic generally, then the DALYs averted in routine practice would continue to be high. There was some uncertainty in the cost per DALY averted figures, with a base case estimate of £44 per DALY averted increasing to £449 per DALY averted when only those with a demonstrated benefit were included. It is likely that other patients did benefit but follow-up data were not available to demonstrate this conclusively. One way of determining whether an intervention is cost-effective is to compare the estimated cost-effectiveness ratio with a threshold ratio, that is, a ratio that decision makers have determined represents value for money. There is no consensus as to the threshold ratio for cost per DALY averted. In the literature, threshold ratios range from a cost per DALY averted of US\$50, as a threshold below which public health interventions are cost-effective in low-income countries (Marseille et al. 1999), and US\$75

per DALY averted, as a ratio where support for expanding services should be given (Jamison et al. 1993). Notwithstanding the difficulties of making comparisons across studies that have used different methods, are based in different countries and use different currencies, the base case estimate of £53 per DALY averted would appear to fall within reasonable limits. Hence, technology transfer using teleophthalmology can be judged to be cost-effective on this basis.

The technology transfer project also resulted in practitioner benefits. Practitioners in South Africa reported satisfaction with the quality of images and comfort with using the teleophthalmology. Furthermore, the majority of cases referred for teleophthalmology by practitioners in South Africa were consultant proxy; that is, the technology transfer tended to substitute for unavailability of consultants locally. This confirms the lack of available staff locally and emphasizes the need for technology transfer projects. In addition, practitioners learnt novel procedures through the technology transfer process that could help future patients at Edendale Hospital. Although this ripple effect has not been quantified, the effect of this learning is likely to increase patient benefit and improve the cost-effectiveness of the project. While it is not possible to aggregate the patient and practitioner benefits into a single measure of cost-effectiveness, in the future it

may be possible to use full cost benefit analysis to value and aggregate benefits accruing to patients and practitioners.

The technology transfer ran for a limited period of time. An important issue for the future is to consider the sustainability of the project. Given the low cost investment from the UK, it should be possible for the UK or other richer countries to devote resources to technology transfer. The main opportunity cost arising from this is that practitioners in the UK have less time to spend with local patients. Nevertheless, practitioners in the UK also valued the experience of technology transfer and were willing to participate. To some extent the success of the project relied on the goodwill of practitioners in the UK to participate, but given that this was the first project of its kind, this was perhaps inevitable. Now that the project has been found to be successful, this provides evidence that could be used to persuade other practitioners to take part in such programmes in the future. Furthermore, other ways of encouraging practitioners to take part could be developed, such as making it part of continuous professional development programmes.

Although the project was between the United Kingdom and South Africa, in the future, once the skill base has improved in South Africa, it would be appropriate to run the service between eye clinics within South Africa. This would then lead to a situation where South Africa could take charge of the development of its health service whilst at the same time lessening the burden of disease. Given the pressure on health care resources in South Africa, funding from the international community is, however, still likely to be required.

The project has not evaluated alternative modes of technology transfer and it could be that, in the future, media such as the Internet provide a feasible and affordable way of delivering technology transfer. This project has demonstrated a method for evaluating technology transfer projects. The overall conclusion is that technology transfer using teleophthalmology is cost-effective in reducing the burden of eye disease and also contributed to the learning of practitioners in South Africa, which in turn should benefit future patients and lead to additional health benefits. If the learning effects could be measured in such a way that they could be included in the cost-effectiveness ratio, this would improve the cost-effectiveness of the project. Using telemedicine to transfer technology is a cost-effective way for richer countries to aid capacity building in the health care systems of poorer countries.

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