4 Hebert M. Telehealth success: evaluation framework development. *Med Inform* 2001;**10**:1145–9
5 Hu PJ-H. Evaluating telemedicine systems success: a revised model. *Proceedings of the 35th Hawaii International Conference on System Sciences*, 2002. See http://csdl2.computer.org/comp/proceedings/hicss/2003/1874/06/187460174b.pdf (last checked 5 July 2005)
6 Scott RE, Coates K, McCarthy GF. The value of an evaluation framework for telehealth initiatives. *Stud Health Technol Inform* 1999;**64**:39–45
7 Wootton R, Hebert MA. What constitutes success in telehealth? *J Telemed Telecare* 2001;**7** (Suppl. 2):3–7
8 Bowns IR, Rotherham G, Paisley S. Factors associated with success in the implementation of information management and technology in the NHS. *Health Inform J* 1999;**5**:136–45
9 Horsfield B, Peterson C. The hierarchy of discourses in the current diffusion of e-health, telemedicine and telehealth in Australia. DCITA Communications Research Forum, 2004. See: http://www.crf.dcita.gov.au/papers2000/horsfield.doc (last checked 17 July 2005)
10 Parkinson C, Hudson L, Hornsby D, Madl R, Collins R. Telehealth: a national, sustainable approach. *7th National Rural Health Conference, Hobart 2003*. See http://www.nrha.net.au/nrhapublic/publicdocs/conferences/7thNRHC/Papers/general%20papers/parkinson_hudson.pdf (last checked 17 July 2005)
11 Lewin Group. *Assessment of Approaches to Evaluating Telemedicine: Final Report, December 2000: Section B*. See http://aspe.hhs.gov/health/reports/AAET/aaet.htm (last checked 17 July 2005)
12 Carson E, Cramp D, Morgan A. Some methodological issues in telemedicine: systems, modeling and evaluation. *International Conference on Information Technology Applications in Biomedicine, Amsterdam,* 1999: 11. See http://ieeexplore.ieee.org/iel5/6788/18221/00842308.pdf?arnumber=842308 (last checked 12 July 2005)
13 Roine R, Ohinmaa A, Hailey D. Assessing telemedicine: a systematic review of the literature. *CMAJ* 2001;**165**:765–71
14 Hailey D, Crowe B. A profile of success and failure in telehealth – evidence and opinion from the Success and Failures in Telehealth conferences. *J Telemed Telecare* 2003;**9** (Suppl. 2):22–4
15 Hailey D, Roine R, Ohinmaa A. Systematic review of evidence for the benefits of telemedicine. *J Telemed Telecare* 2002;**8** (Suppl. 1): 1–30
16 KPMG Consulting. *Review of the Literature on Evaluation and Telehealth*. Canberra: Commonwealth Department of Health and Aged Care/Australian and New Zealand Telehealth Committee, 1999

Referral patterns in a global store-and-forward telemedicine system

R Wootton*, K Youngberry*, R Swinfen† and P Swinfen†

*Centre for Online Health, Level 3, Foundation Building, Royal Children's Hospital, Herston 4029, Australia; †Swinfen Charitable Trust, Canterbury, UK

Summary

We examined the nature of the referral patterns in the email telemedicine network operated by the Swinfen Charitable Trust with a view to informing long-term resource planning. Over the first six years of operation, 62 hospitals from 19 countries registered with the Trust in order to be able to refer cases for specialist advice; 55 of these hospitals (89%) actually referred cases during this period. During the first six years of operation, nearly 1000 referrals were submitted and answered, from a wide range of specialty areas. Between July 2002 and March 2005 the referral rate rose from 127 to 318 cases per year. The median length of time required to provide a specialist's response was 2.3 days during the first 12 months and 1.8 days during the last 12 months. Five hospitals submitted cases for more than four years (together sending a total of 493 cases). Their activity data showed a trend to declining referral rates over the four-year period, which may represent successful knowledge transfer. There is some evidence that over the last three years the growth in demand has been exponential, while the growth in resources available (i.e. specialists) has been linear, a situation which cannot continue for very long before demand outstrips supply.

Introduction

The Swinfen Charitable Trust (SCT) has operated a low-cost email telemedicine system to support doctors in developing countries since mid-1999.[1] The network is now in its seventh year of operation, making it one of the longest-running such telemedicine networks, i.e. operated for charitable purposes and dealing mainly with clinical work. During the first six years of operation, nearly 1000 referrals were managed. For the first three years, email messages were handled manually; subsequent operations have depended on an automatic message-handling system.[2,3]

We have previously described the overall performance of the network and the referring doctors' views about it.[4] To operate successfully, any telemedicine network – whether realtime or store-and-forward – must balance demand with supply, i.e. requests for clinical consultations must be met within an agreed time. There is a dearth of reports about

Correspondence: Professor R Wootton, Centre for Online Health, Level 3, Foundation Building, Royal Children's Hospital, Herston 4029, Australia (*Fax: +61 7 3346 4705; Email: r_wootton@pobox.com*)

methods for doing this in practice, and how well networks actually perform.[5] The present study was carried out to examine the nature of the referral patterns in the SCT network with a view to informing long-term resource planning.

Methods

Data collected during the initial phase of network operation (when email messages were handled manually) and data collected automatically from the second phase (when message-handling was computerized) were collated in spreadsheet form for analysis.

Results

Over the first six years of operation, 62 hospitals from 19 countries registered with the Trust in order to be able to refer cases for specialist advice. A total of 55 of these hospitals (89%) actually referred cases during this period. The following statistics are based on referrals in the first 5 years and 9 months of operation, i.e. from July 1999 to March 2005.

Referrals from the hospitals

Hospitals which had been members of the network for longer tended to have referred more cases (not unexpectedly). The correlation coefficient was significant ($r = 0.73$), although the relationship was heavily influenced by the performance of four hospitals, which collectively provided 469 referrals (51% of the total) (Figure 1).

At the time of the study in March 2005, seven of the 49 hospitals (14%) had not referred a case for more than one year and so they were classed as 'inactive' and excluded from the subsequent analysis. Thus, there were 42 'active' hospitals, which had continued to send cases (i.e. their most recent case had been referred less than one year ago at the time of the study). These 42 fell roughly into two groups, i.e. they could be divided into 18 hospitals (43%) which sent cases regularly (where 'regularly' was defined as an average referral rate of one case per month or greater), and 24 hospitals (57%) which sent them less frequently.

In parallel with the growth in numbers of hospitals referring cases (Figure 2), there was a growth in the numbers of volunteer specialists who answered them (Figure 3). At 31 March 2005, there was a total of 144 specialists from a wide range of health-care disciplines. These specialists were located in 12 countries.

Operational performance of the network

During the period from 1 July 1999 to 31 March 2005 (2069 days), 912 cases were referred. Detailed statistics were not available for the period before July 2002, when

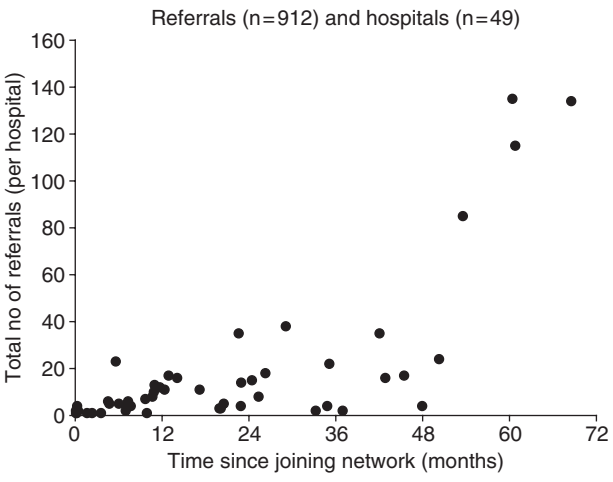

Figure 1 Relation between the number of cases referred by a hospital and the length of time it had been a member of the network

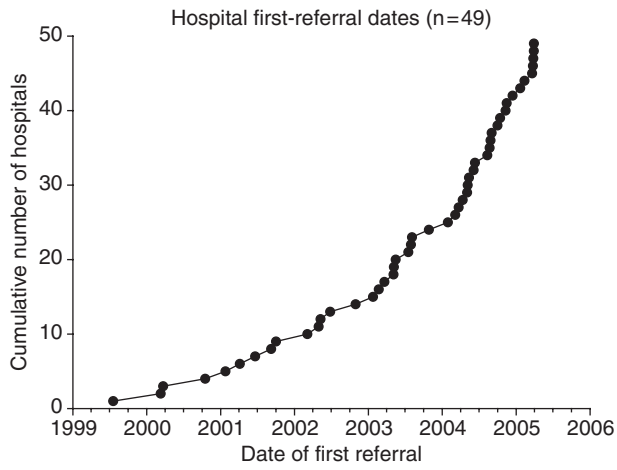

Figure 2 Hospitals and the dates on which they first referred cases

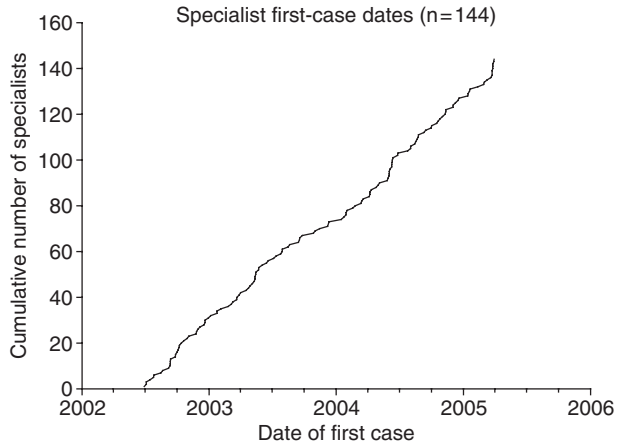

Figure 3 Specialists and the dates on which they first replied to referrals

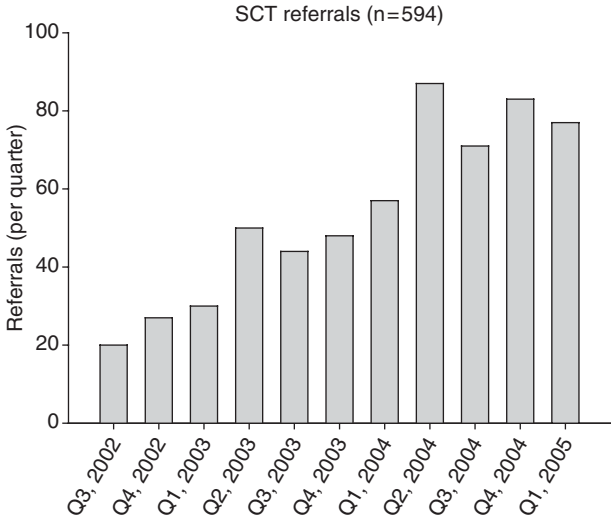

Figure 4 Referral rate

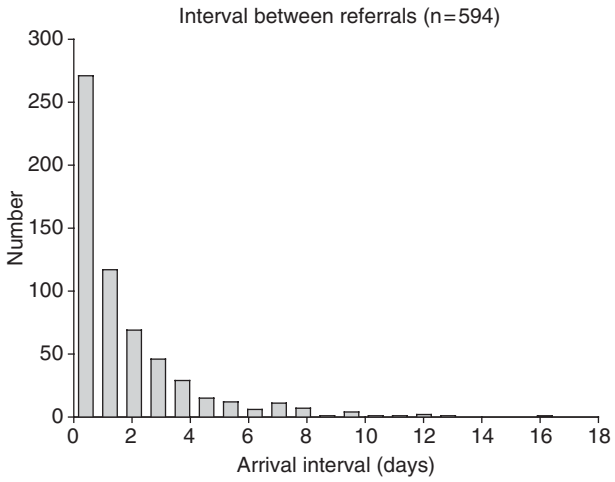

Figure 5 Frequency distribution of inter-case arrival times

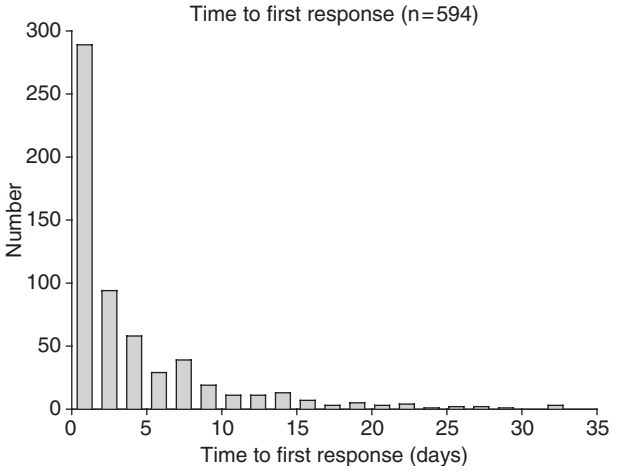

Figure 6 Frequency distribution of case-answering times

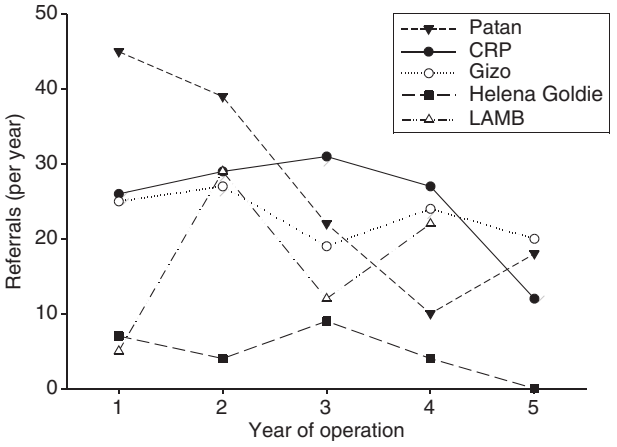

Figure 7 Referrals from the five hospitals longest in the system

Table 1 Network demand (number of referrals) and supply (time to specialist's response) – first 12 months of automatic message-handling and last 12 months

	number of referrals	Time to specialist's response (days)	
	n	Median	Interquartile range
First 12 months (1/7/02–30/6/03)	127	2.3	0.8–5.6
Last 12 months (1/4/04–31/3/05)	318	1.8	0.6–4.9

records were kept manually, so the following analysis is restricted to the epoch July 2002–March 2005 (a total of 594 cases).

Demand

The annual referral rate was 127 during the first 12 months of automatic message handling and had risen to 318 during the last 12 months (Figure 4). The distribution of case-arrival times is shown in Figure 5.

Supply

The median length of time required to provide a specialist's response was 2.3 days during the first 12 months and 1.8 days during the last 12 months (Table 1). The distribution of case-answering times is shown in Figure 6.

Pattern of referral from the five hospitals longest in the system

Five hospitals submitted cases for more than four years (together sending a total of 493 cases). These hospitals were located in Bangladesh (2), the Solomon Islands (2) and Nepal (1). Their activity data show a trend to declining referral rates over the four-year period (Figure 7).

Discussion

Referral patterns

Five hospitals continued to submit cases for more than four years. One may conclude that they did so because they found the service useful,[4] rather than because of the novelty effect of telemedicine. The reasons for the long-term decline in referral rate are not easily defined, but probably include staff turnover and telecommunication problems. Nonetheless, a fall in referral rates from a given hospital may not represent a failure. On the contrary, it may actually reflect success if the drop in referrals results from local knowledge that has been gained as a result of using telemedicine.

Modelling demand and supply

Figure 5 shows that the distribution of case-arrival times is approximately exponential, i.e. there is some evidence that arrival times are Poissonian. This would be expected if a large number of independent event streams were merged together, and if events in each stream occurred at a very low rate – the resulting stream would then be approximately a Poisson process with exponential intervals. Figure 6 shows that the distribution of case-answering times is also approximately exponential, i.e. there is some evidence that service times are also Poissonian.

By convention, the interrelation of demand and supply is analysed in a queuing model.[6] Such models assume that the arrival times and service times follow an exponential distribution – for which there is some evidence in the case of the SCT telemedicine network. This is important because simple M/M/1 queuing models, for example, are well understood.[6] There are closed, analytic solutions which describe their performance. Unfortunately, the real situation is more complicated. At least an M/M/n model would be required to model the operation of the SCT network, for which an analytic solution has yet to be described. However, simulation is possible and this represents a fruitful area for future telemedicine research.

Planning network resources

A successful telemedicine network must balance supply and demand. In the present context, the SCT must balance the growth in the number of hospitals which request services with the growth in the number of specialists who can provide them. There is some evidence that over the last three years the growth in demand has been exponential (Figure 2), while the growth in resources (specialists) has been linear (Figure 3), a situation which cannot continue for very long before demand outstrips supply. There are signs that this is beginning to occur, as shown in Figure 8. This has important implications for network planning.

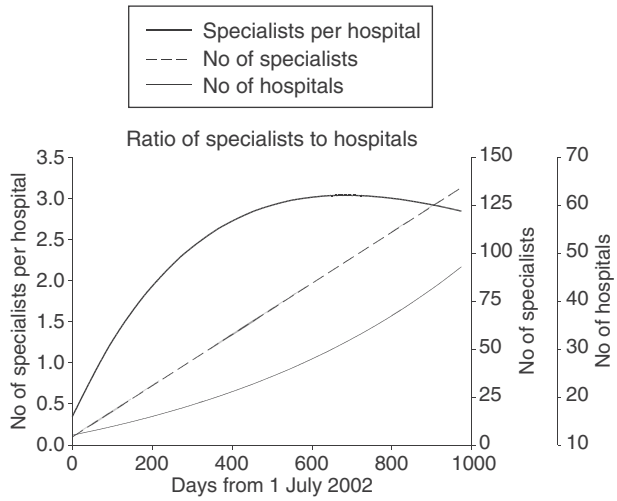

Figure 8 Numbers of specialists and numbers of hospitals, since 1 July 2002

Conclusion

The SCT operation is an example of altruistic telemedicine work. It uses a 'low-tech' approach; it appears to be useful, cost-effective and sustainable. As it grows, it is crucial that network resources keep pace with network demands. There is some evidence that network demand is beginning to outstrip supply, a situation which cannot continue for very long before it will lead to trouble.

References

1 Swinfen R, Swinfen P. Low-cost telemedicine in the developing world. *J Telemed Telecare* 2002;**8** (Suppl. 3):63–5
2 Wootton R. Design and implementation of an automatic message-routing system for low-cost telemedicine. *J Telemed Telecare* 2003;**9**:44–7
3 Swinfen P, Swinfen R, Youngberry K, Wootton R. A review of the first year's experience with an automatic message-routing system for low-cost telemedicine. *J Telemed Telecare* 2003;**9**:63–5
4 Wootton R, Youngberry K, Swinfen P, Swinfen R. Prospective case review of a global e-health system for doctors in developing countries. *J Telemed Telecare* 2004;**10**:94–6
5 Krupinski E, Webster P, Dolliver M, Weinstein RS, Lopez AM. Efficiency analysis of a multi-specialty telemedicine service. *Telemed J* 1999;**5**:265–71
6 Gross D, Harris CM. *Fundamentals of Queueing Theory*. 2nd edn. New York: John Wiley, 1985