Economic Evaluation of the Role of Telemedicine in Paediatric Cardiology

Final Report

Robin Dowie
Hema Mistry
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On behalf of the
TelePaed Project Team

September 2005

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CONTRIBUTORS, ACKNOWLEDGEMENTS AND CONTACTS

The TelePaed project is an economic evaluation of the role of telemedicine in paediatric and perinatal cardiology and this is the fourth and final report. (Details of the other reports appear below.) The project was commissioned by the Department of Health under the Information and Communication Technology Research Initiative (see http://www.disco.port.ac.uk/ictri/). The project was conducted in the Health Economics Research Group (HERG) at Brunel University in collaboration with the Royal Brompton and Harefield NHS Trust. The research team at Brunel included Robin Dowie, who had overall responsibility for the project, Hema Mistry, health economist, Tracey Young, statistician, now in Health Economics and Decision Science at the University of Sheffield, and Gwyn Weatherburn, who is now in the Research Centre for Health Studies at Buckinghamshire Chilterns University College. The research team members in the Department of Paediatric Cardiology at the Royal Brompton Hospital were Dr Rodney Franklin, Dr Helena Gardiner, Dr Michael Rigby and Dr Giselle Rowlinson, who is now at the Great Ormond Street Hospital for Sick Children. The research team is most grateful to the Department of Health and the Charitable Funds Committee of the Royal Brompton and Harefield NHS Trust for funding the project.

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The reports from the project were prepared at Brunel on behalf of the TelePaed Project Team. The corresponding author is:

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The earlier reports from the project: are:

Dowie R, Young T, Mistry H, Weatherburn G (on behalf of the TelePaed Project Team) (2003) Economic evaluation of the role of telemedicine in paediatric cardiology. First report: Paediatric cardiology outpatient services. Uxbridge, Brunel University. (Submitted to the Department of Health, December 2003)

Dowie R, Mistry H, Young T, Weatherburn G (on behalf of the TelePaed Project Team) (2004) Economic evaluation of the role of telemedicine in paediatric cardiology. Second report: Fetal cardiology services. Uxbridge, Brunel University. (Submitted to the Department of Health, September 2004)

Dowie R, Mistry H, Young T, Weatherburn G (on behalf of the TelePaed Project Team) (2005) Economic evaluation of the role of telemedicine in paediatric cardiology. Third report: Neonatal cardiology services. Uxbridge, Brunel University. (Submitted to the Department of Health, May 2005)

EXECUTIVE SUMMARY

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Context, objectives and research setting

1. Although the annual incidence of congenital heart disease in the United Kingdom appears constant, pressures are mounting on the nation's 15 specialist paediatric cardiology units. Substantial improvements in first year survival rates for complex cases have resulted in a sustained expansion in cohorts of children requiring long-term monitoring, while simple conditions frequently require intermittent monitoring. Paediatric cardiologists also assess infants and children with asymptomatic murmurs to exclude heart disease, while perinatal cardiologists assess pregnant women to confirm or exclude a heart abnormality in their fetus.

2. Most paediatric cardiology units hold outreach clinics in district hospitals on a monthly, bi-monthly or quarterly basis, and waiting times for routine first appointments historically have often been many months. If a rapid opinion is required, the child will likely be transported to the regional centre by the parents or an ambulance. Tertiary fetal medicine centres, where perinatal cardiologists hold sessions, usually do not operate peripheral outreach clinics, so many women in the second trimester of their pregnancy make lengthy journeys for a specialist assessment.

3. In the late 1990s, telemedicine and telecare were seen as having a key role in the Government's plans to modernise the NHS. Reliability of the technology for sharing cardiac information between clinicians about children, neonates and unborn babies had already been demonstrated, but there was no robust information on the cost effectiveness of paediatric telemedicine services. The situation was unchanged in 2003. [Hailey et al, 2004]

4. Under the auspices of the NHS Information & Communication Technology Research Initiative, an economic evaluation was undertaken of a telemedicine service for the provision of specialist advice on fetal and paediatric cardiac care to clinicians in district hospitals. The project aimed to identify and value NHS costs associated with the introduction of telemedicine and costs incurred by families, to assess the health-related quality of life of patients receiving telemedicine and patients seen conventionally, and to establish the cost effectiveness of the technology. Four project reports were prepared. The previous reports examined separately the role of the telemedicine service in obstetric care, neonatal care, and paediatric care while this, the final report, covers the full spectrum of care.

References cited in the Executive Summary are listed at the end of the Final Paper.

5. Five hospitals participated in the project: a London specialist hospital (the Royal Brompton Hospital) and four district hospitals in Essex and Kent in which specialists from the Royal Brompton held outreach clinics. The hospitals were between 35 and 65 miles from central London. Outreach clinics were held every three or four months in three hospitals, and monthly in one hospital. Although the obstetric departments in the hospitals recorded 3100 to 3800 maternal deliveries annually, the neonatal units provided different levels of care.

6. Packages of telemedicine equipment designed for use with ISDN-6 telephone lines were installed in the district hospitals and training in using the equipment was provided. Advanced tuition was also provided in fetal heart ultrasonography and neonatal and paediatric echocardiography. The telemedicine service provided remote access to paediatric cardiologists based in the Royal Brompton and to a perinatal cardiologist who worked in a fetal medicine centre. Two hospitals utilised the telemedicine service from August 2001, and the service was available to the other hospitals from February 2002. The consultants in the hospitals decided how the service would be utilised in terms of case selection.

Methods

7. Three groups of patients in the district hospitals were eligible for teleconsultations.

i) Pregnant women referred for detailed ultrasound scans of the fetal heart;

ii) Newborn babies with a suspected heart problem;

iii) Infants and children referred for a cardiac opinion usually in an outreach clinic.

Project facilitators in the hospitals prospectively audited the clinical care of all newly referred patients in these groups between May, 2001 and July, 2002. Babies and children who were not discharged immediately by the specialists were followed up for 3 to 12 months depending when they first became eligible. Pregnant women were followed up until they were delivered.

8. The economic evaluation adopted a cost consequence approach from the dual viewpoints of NHS acute hospital services, and patients and their families. Clinical outcomes of specialist assessments were recorded. Postal surveys conducted over 10 months assessed the health-related quality of life of pregnant women and children after they saw the specialists. The survey of women was confined to the two hospitals that customarily referred their patients to the perinatal medicine service linked to the Royal Brompton. The women's questionnaire incorporated HADS and the EQ-5D health status instrument. [Zigmond and Snaith, 1983; Brook, 1996] For children under 2 years, mothers completed the QUALIN instrument [Manificat et al, 2000] while the mothers of older children completed the PedsQL™ instrument. [Varni et al, 2001] Costs incurred by the patients or families when visiting a hospital locally or in London were recorded in the questionnaires.

9. Items on resource use events were entered in a specially designed audit database: they covered hospital contacts; clinical activities; ambulance journeys; teleconsultations; and personnel who were consulted. An observational study recorded mean times for outreach clinic attendances, and timings for the teleconsultations were audited. Costs for 2001-2 were attributed to the resource use items using information provided by finance officers and business managers in the district hospitals, the Royal Brompton and two fetal medicine centres. As it was not possible to obtain all the required unit cost data from all hospitals, weighted unit costs were used for attributing cost per resource unit item. Medical staff time (calculated in minutes) was costed using NHS salary scales and the manual by Netten and Curtis [2002]. Annual equivalent costs for the telemedicine equipment packages were estimated over an assumed lifetime of 5 years with a discount rate of 3.5%. The annual equivalent cost and ISDN-6 installation cost for each hospital was divided by the total teleconsultations to derive a technology cost per consultation.

10. A cohort approach was adopted for the cost analyses, whereby the costs of patients referred via telemedicine were compared with the costs of patients referred conventionally over the 15-month period. Bootstrapped mean costs per patient were generated for the initial consultation with a specialist, for 14 days inclusive of the initial consultation, and for a maximum period of 6 months. Most pregnant women delivered their babies within the 6-month period, so the costs applied to their antenatal care. Two sets of cost results were prepared. The first compared the alternative referral methods for all patients, and for the three patient groups. The second focused on the two hospitals that had access to the telemedicine service for 12 months, because the clinicians used the technology for different patients – newborns and older children in DGH2, and newborns and women in DGH3. The sensitivity analysis examined two scenarios. The first took account of travel costs incurred by women when journeying to London or their local hospital; the second considered the impact on patient costs when telemedicine facilities in a hospital are shared with other users.

11. Modelling was undertaken to determine whether the results from the analyses of the telemedicine usage could be generalised to district hospitals elsewhere. First, logistic regression models were fitted to all referred patients in the three patient groups to identify variables that were significant predictors of whether patients might be assessed via telemedicine. Multivariate logistic regression models were then applied to the patient groups in order to predict referral mode selection for each patient. The models were also fitted to the observed caseloads to measure their predictive accuracy. Cost analyses were performed on the results obtained from the modelling after adjustments were made to the observed costs.

Results

12. The hospitals referred 504 eligible patients over 15 months and the telemedicine service was used for 117 (23%) of these referrals. The service was used for 52 (21%) of the 248 pregnant women, 17 (43%) of the 40 newborn babies, and 48 (22%) of the 216 older children. One hospital only (DGH3) referred women via telemedicine; three hospitals referred newborn babies via telemedicine; and three hospitals used the service for older children.

13. *Demographic and clinical attributes.* Women referred via telemedicine were younger by 3½ years than women who travelled to London, and most (79% vs 41%) had a greater than average risk of conceiving a fetus with congenital heart disease (CHD). These differences were statistically significant. The purpose of most referrals (90% telemedicine, 81% conventional) was to screen the fetus. Although no statistically significant difference was observed among the neonates, 35% of the London transfers had symptoms suggestive of critical CHD compared with 12% of the telemedicine babies. Children assessed via telemedicine were similar in age to the clinic attenders (means of 4½ years and 5 years respectively) and most patients were asymptomatic (79% telemedicine and 68% clinic attenders, a non-significant difference).

14. *Specialist outcome.* For 15% of all women a fetal diagnosis of severe or moderately severe CHD was made, but there was no significant difference between referral methods in the proportions of women diagnosed in this way. In contrast, for the newborn babies, the patterns of care following the specialists' assessments differed significantly: 88% of the 17 telemedicine babies continued to receive their care in the district neonatal units, while 61% of the 23 transferred babies were retained in the specialist units. Three-quarters (77%) of all children were assessed for heart murmurs, most of which were normal or self-correcting, and there was no significant difference in the outcomes: the specialists discharged immediately 42% of the telemedicine children and 45% of the clinic attenders.

15. *Quality of life.* Analyses of the questionnaires from 26 women assessed via telemedicine and 11 who travelled to London found that the EQ-5D tariffs for the London travellers, derived from five statements on mobility, self-care, usual activities, pain and discomfort, and anxiety and depression, were significantly lower (p=0.031). Mothers completed questionnaires about 12 telemedicine children and 46 clinic attenders. Telemedicine patients appeared to experience a slightly better quality of life, both the children under 2 years for whom the QUALIN instrument was completed, and the older children who had been assessed by the PedsQL™ instrument.

16. *Initial consultation costs*. The mean NHS cost for the initial consultation with a specialist for all 117 patients using the telemedicine service was £411 (95% CL £352 to £481). The comparative cost for the 387 conventional referrals was lower at £277 (95% CL £212 to £389), but the difference was not statistically significant. The telemedicine referral option was significantly more costly for the patient groups of women and older children, but most of the differential was attributable to the technology and its operating costs. For the newborn babies, in contrast, the telemedicine referral option was significantly cheaper because only 1 baby was transferred by ambulance to London following a teleconsultation.

17. *14-day costs.* The disparity between the mean cost per patient for all telemedicine referrals versus all conventional referrals widened to £574 over the 14-day period (£1,437 (95% CL £888 to £2,305) v £863 (95% CL £582 to £1,269), but the difference was still not statistically significant. Newborn babies formed the patient group with the largest cost differential - £4,250 in favour of the telemedicine cases. A specialist intensive care cot day of £1,020 was one of the most costly hospital items, and the London-referred babies spent an average of 5½ days receiving specialist care in the 13 days following their transfer to London compared with 1½ days for the telemedicine transferees.

18. *6-month maximum costs.* After six months, once again there was no statistically significant difference in the mean costs for all patients referred either via telemedicine or conventionally, although telemedicine remained more costly overall (£3,350 (95% CL £2,035 to £6,020) v £2,172 (95% CL £1,670 to £3,132)). For newborn babies and older children, telemedicine was the cheaper option. Antenatal care incorporating a teleconsultation was, however, dearer than care involving a visit to London (£925 (95% CL £800 to £1,097) v £714 (95% CL £632 to £849)) (p=0.052). This cost differential was mainly attributable to local variations in the delivery of maternal care. The telemedicine cases were from DGH3 and all women referred from this hospital made an average of 10 visits to district clinics during the later months of their pregnancies compared with 5 visits for the women referred from the three other hospitals. When the women in DGH3 alone were considered, the mean costs for antenatal care were higher for the telemedicine referrals at £925 (95% CL £800 to £1,097) compared with £784 (95% CL £638 to £981) for the London referrals.

19. *Experience in two hospitals.* The telemedicine facilities were used over 12 months for newborn babies and older children in DGH2 and for newborn babies and women in DGH3, and in each hospital, after 6-months follow up, the mean cost per telemedicine referral from the combined patient groups was lower than the mean cost for patients who were referred conventionally. But the cost difference within each hospital was not statistically significant.

20. *Family costs.* The mean mileage of the return journeys made by women to London hospitals was 100 (SD 28) and they travelled either by train or car; journeys by telemedicine women to the local hospital (DGH3) were mostly made by car and the mean return distance was 9 (SD 9) miles. Consequently, the median costs of the hospital visits, inclusive of travel, any loss of income, and incidental expenses, were £50.36 for travellers to London and £12.59 for women attending DGH3 (p=0.002). The London travellers were usually accompanied by an adult, and they were away from home for 5½ hours. Children who underwent teleconsultations attended their local hospital just as if they were seeing the specialists in an outreach clinic, so there was no difference in the patterns of family costs.

Sensitivity analysis

21. The sensitivity analysis that took account of the travel costs incurred by women from DGH3 found remote consultations were still the more costly referral strategy, the bootstrapped mean costs per DGH3 referral being £149 for teleconsultations and £91 for London visits (p<0.001). The teleconferencing equipment supplied to DGH1 was installed in a central suite and it was used in 2004-05 for cancer network teleconferences with about 10 patients being discussed during each session. In this sensitivity analysis the costs of the telemedicine service for DGH1, inclusive of the additional telephone charges taken from invoices for 2005, were shared among the 11 observed cardiac users over 6 months and 300 cancer patients (the estimated number of cases using the service in 6 months). According to this scenario, the bootstrapped mean cost for the initial consultations for the 11 cardiac patients was now slightly lower than the mean cost for the 48 children seen directly by the specialists (£240 (95% CL £178 to £515) v £268 (95% CL £168 to £712)), (p=0.901).

Predicting the costs of telemedicine referrals

22. The logistic regression modelling identified statistically significant predictors for telemedicine referral selection: for women, those with a high risk for a fetal cardiac anomaly were more likely to be telemedicine referrals; among newborn babies, less urgent cases were more likely to be referred in this way; and for children, the policy in the hospital over the uptake of the telemedicine service was the strongest predictor. The overall predictive accuracy of the models was 64% (97 of the 117 actual telemedicine referrals were predicted as telemedicine cases, and 227 of the 387 conventional referrals were predicted to use this method). The cost analysis for the initial consultation, based on the adjusted costs for the predicted cases, found the mean cost per telemedicine referral was significantly lower than the mean cost per conventional referral (£195 (95% CL £177 to £217) v £393 (95% CL £288 to £566)) (p=0.003).

Discussion

23. Although no statistically significant difference in presenting clinical circumstances was observed, telemedicine patients were generally in a better state of health. The patient cost results over six months also indicated that the telemedicine cohorts had lower utilisation levels of NHS hospital resources, although not significantly so, than the conventionally referred cohorts.

24. These equivocal 6-month cost results may be set beside the results from the `virtual outreach' evaluation of a referral service linking general practitioners with consultants in 8 specialties in 2 hospitals, using PC-based technology and ISDN-2 telephone links. The 6-month mean costs for resource events associated with the presenting condition were £393 per patient in the virtual outreach group and £286 per patient in the standard outpatient group ($p<0.0001$), with the difference being attributed to the excess cost of the initial consultation. [Jacklin et al, 2003] But the two studies differed in a key respect: the virtual outreach patient population did not include emergency referrals. Virtual outreach patients were offered a follow-up hospital appointment more often that the comparator patients (52% v 41%), $p<0.001$), unlike in this project where the rebooking rates were similar for both groups of referred children (58% telemedicine, 55% clinic attenders). The different specifications of the video conferencing systems may have been a contributing factor. The equipment packages for this project were designed specifically to transmit cardiac ultrasound images for diagnostic purposes over ISDN-6 lines. Heart sounds could be transmitted also using electronic stethoscopes, although the stethoscopes were used infrequently.

25. The transmission of skilfully performed echocardiograms is essential in telecardiology and the project relied on the district paediatricians having access to suitable echocardiography machines; one hospital purchased a machine before taking up the telemedicine service. Advanced scanning tuition was offered to the paediatricians and obstetric sonographers and the training was reinforced during the teleconferences. (Improvements in echocardiography skills are seen as an educational benefit arising from paediatric cardiology. [Casey, 1999]) The district clinicians found learning to use the telemedicine system was less problematic and time consuming than updating their skills or acquiring sufficient expertise in scanning the heart for remote diagnosis. The clinicians also stressed the importance of having mutual trust and professional respect between the specialists and the district staff. Easy, and safe, access to the telemedicine equipment within the paediatric or obstetric department was an important incentive to using the service. Teething problems when the technology was first used were rapidly resolved.

26. For the surveyed parents, the telemedicine service had two commanding attributes. It could reduce appointment waiting times for children referred for screening, and district paediatricians could use the technology for patients they were particularly concerned about, thus minimising the need for journeys to London. As to the technology, evidence from our survey and the virtual outreach project [Wallace et al, 2002] showed that patients and parents found teleconsultations to be acceptable as long as technical problems did not arise.

27. The telemedicine service in the district hospitals supplemented, rather than substituted, existing specialist services. The schedules for holding outreach clinics at three to four monthly intervals were unchanged. For babies and children with moderate or severe symptoms, the telemedicine service facilitated rapid access to specialist advice, thus avoiding in many cases ambulance transfers to a cardiac centre with a vacant cot or bed. By allowing the district clinicians to determine the roles for the telemedicine service, the hospitals' use of the service became embedded in routine practice. All four hospitals were still using the telemedicine service in 2005.

28. In the years since commissioning the project, the Government's reforms of the NHS have focused even more on access to services, with the 18-week maximum wait from referral to hospital treatment now a national target by 2008. The Paediatric and Congenital Cardiac Services Review Group has recommended that in order to minimise the 'patient journey', all paediatric cardiac units should hold peripheral outreach clinics in premises with suitable echocardiography facilities. [DoH, 2003a] Concerted efforts in raising standards of antenatal screening in district maternity services are being made, with improved fetal heart ultrasound seen as a priority since marked regional variations exist in the practice of visualising cardiac outflow tracts during second trimester anomaly scans. [UK National Screening Committee, 2005] These drivers for quality improvement will place even greater demands upon paediatric cardiologists (a specialty with 63 consultants in England in 2004).

29. Innovative use of telemedicine services alongside conventional paediatric and perinatal cardiology services would enhance patient access, and would be consistent with the recommendations of the House of Commons Health Committee in its 2005 report on new medical technologies within the NHS. This evaluation of an exemplar service has provided insights into factors that promote, and hinder, the uptake of the telemedicine technology; it has produced information on referral patterns in four hospitals; and, through the application of modelling, identified key variables for predicting telemedicine caseloads in district hospitals elsewhere. Most importantly, the research has found that operating a telemedicine service alongside conventional referral services can be cost neutral in the longer term.

PREFACE

PREFACE

The TelePaed project evaluated the cost effectiveness of using telemedicine to provide specialist advice on fetal or paediatric cardiac care to consultant obstetricians and paediatricians in district general hospitals. Four hospitals in Essex and Kent were involved and the specialists were based in the Royal Brompton Hospital in west London. The Royal Brompton and Harefield Hospitals NHS Trust, which forms the largest cardiothoracic centre in the United Kingdom, has long-standing telemedicine links with hospitals in Europe.

The telemedicine service allowed district clinicians to obtain the advice of specialists in two main ways. They could hold face-to-face consultations with the patient present and transmit live ultrasound images from an echocardiogram machine and heart sounds using an electronic stethoscope. Alternatively, they could transmit pre-recorded videoed ultrasound images (the `store and forward' approach) and view them during live consultations with the specialist, but in the absence of the patients. The telemedicine service was available to obstetricians and obstetric sonographers for fetal cardiology advice and to paediatricians or neonatologists for cardiology advice on newborn babies, and older infants and children.

The four district hospitals were provided with telemedicine equipment as part of the project, but they were randomised at the start of the project either to use the equipment during the six-month intervention phase (i.e. for two intervention sites) or to delay using the equipment until after the intervention phase (for two control sites). Uptake of the telemedicine service in the intervention sites was slower than anticipated and the fieldwork was extended by six months to allow all four hospitals to be studied while they utilised the service.

Three patient groups were studied:

- Pregnant women at risk of a fetal heart anomaly;
- Newborn babies suspected of having a heart problem;
- Older infants and children for whom the district consultant paediatricians requested a cardiac opinion. These patients normally were seen in outreach clinics held by specialists in the district hospitals rather than in the Royal Brompton Hospital.

The fieldwork was conducted prospectively. Eligible patients were followed up, in terms of their hospital events, for 3 to 12 months. NHS hospital costs were collected for the clinical and telemedicine events. Postal questionnaires were sent to pregnant women and the parents of infants and children to assess the patients' quality of life, the costs incurred by families when attending hospital, and, for the parents, their views about the type of consultation their child had (i.e. face-to-face with the specialist or via telemedicine).

To facilitate the analysis and interpretation of project's results, the three patient groups were covered by separate reports – see page ii for details. Each report assessed the cost effectiveness of operating a telemedicine service for a single group of patients: a paediatric cardiology outpatient service; a fetal cardiology service; and neonatal cardiology service. As patterns in the uptake of the telemedicine service differed among the four hospitals, logistic regression modelling was undertaken to ensure the best use was made of the project's datasets. The executive summaries from the three reports form Appendix A to this report.

Structure of the final report

This final report assesses the cost effectiveness of operating a telemedicine service which was available for all three groups of cardiology patients in the district hospitals. The analyses are based on the combined datasets from the first three reports.

The centrepiece of the report is an extended paper intended for submission (in a shortened form) to an academic journal. It presents the results from the economic evaluation, and the sensitivity analysis considers the impact of sharing the telemedicine service with other users within a hospital. Additional material supporting the results is incorporated in Appendices C to F. The discussion section of the paper addresses wider issues relating to the role of telemedicine services in bridging the secondary and tertiary sectors in the NHS, and the relevance of the evaluation in the field of paediatric and perinatal cardiology.

Logistic regression modelling was undertaken to see whether the results from the analyses of telemedicine usage in the main paper could be generalised to district hospitals elsewhere. The results from the modelling are presented in Appendices G and H. During 2004-5, two conference submissions based on the project were accepted: a poster on the application of propensity score matching in evaluating telemedicine use, and an oral presentation on parental acceptability of teleconsultations. The conference abstracts are in Appendices I and J. Finally, in Appendix K, there is a qualitative analysis of the views of district hospital staff on the telemedicine service, which they expressed after the fieldwork was completed.

As the telemedicine service was still operating in 2005, an Epilogue on page 34 summarises the ongoing arrangements in the district hospitals and the Royal Brompton Hospital.

FINAL PAPER

Telemedicine in paediatric and perinatal cardiology: an economic evaluation of a service linking district hospitals with a tertiary paediatric cardiac centre

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Introduction

Although the annual incidence of congenital heart disease per 1000 live births in the United Kingdom appears constant at 1.5 cases for complex abnormalities and 4.5 cases for simple conditions [DoH, 2002a; Petersen at al, 2003], pressures are mounting on the nation's 15 specialist paediatric cardiology units. Substantial improvements in first year survival rates for complex cases following surgery or catheterisation have resulted in a sustained expansion in the cohorts of children requiring long-term monitoring [Petersen op cit] while simple conditions frequently require intermittent monitoring. Paediatric cardiologists also assess infants and children with asymptomatic murmurs to exclude heart disease, while perinatal cardiologists assess pregnant women to confirm or exclude a fetal heart abnormality. Most paediatric cardiology units hold outreach clinics in district hospitals on a monthly, bi-monthly or quarterly basis, although the waiting times for first appointments are often many months. [Wagstaff et al, 1998] If a rapid opinion is required, the child will most likely be taken to the regional centre by the parents or by ambulance. Tertiary fetal medicine centres, where perinatal cardiologists hold sessions, usually do not operate peripheral outreach clinics, so many referred women in the second trimester of their pregnancy make lengthy journeys for a specialist assessment.

In the late 1990s, telemedicine and telecare were seen as having a key role in the Government's plans to modernise the NHS: the technologies would help "to eliminate unnecessary travel and delay for patients by providing remote on-line access to services, specialists and care, wherever practicable". [NHS Executive, 1998] Reliability of the technology for sharing cardiac information between clinicians about adults, children, neonates and unborn babies had already demonstrated [Nitzkin at al, 1997; Belmont et al, 1995; Finley et al, 1997; Casey et al, 1996; Fisk et al, 1996], but there was no robust information on the cost effectiveness of paediatric telemedicine services. [Hersh et al, 2001] The situation was unchanged in 2003, according to a systematic review of 16 paediatric telecardiology applications (1 being in the UK [Mulholland et al, 1999]), and the overall conclusion of the reviewers was that the available economic studies did not provide enough high quality information for decision making on telecardiology applications. [Hailey et al, 2004]

Under the auspices of the NHS information and communication technology research initiative, an economic evaluation was undertaken of a telemedicine service for the provision of specialist cardiology advice to clinicians in district hospitals. The telemedicine service was available to clinicians in the paediatric departments, neonatal care units and obstetric departments. Face-to-face teleconsultations between district clinicians and specialists were held, when either the patient was present and live or pre-recorded videoed ultrasound images were transmitted, or videoed ultrasound images were transmitted in the absence of the patient (the `store and forward' approach). District hospitals were randomised either to use the telemedicine service immediately, or to delay its use. The clinicians in each hospital decided how the service would be utilised.

Methods[#]

Setting

Four district general hospitals (DGH) in south-east England participated and they are identified as DGH1, DGH2, DGH3 and DGH4. The hospitals were between 35 and 65 miles from central London. The Royal Brompton Hospital in west London was the specialist telemedicine centre. This hospital has long-standing telemedicine links with hospitals in Europe. [Tsilimigaki et al, 2001] Consultant paediatric cardiologists from the Royal Brompton held outreach clinics in the paediatric departments of the district hospitals: monthly at DGH3, and every three months or four in the other hospitals. Although the obstetric departments in the hospitals recorded between 3100 and 3800 maternal deliveries annually, the neonatal units had different functions: DGH3 had a Level III neonatal intensive care unit providing comprehensive medical neonatal care; the units in the other hospitals provided Level II high dependency care and short-term intensive care.

Packages of telemedicine equipment were installed in the four district hospitals. The equipment items included a Tandberg video conferencing system mounted on a trolley, additional monitors, a video recorder, an object camera visualiser, and an electronic stethoscope sender to enable heart sounds to be transmitted. The telemedicine suite in the Royal Brompton was already comprehensively equipped, but in addition an electronic stethoscope receiver was installed. The telemedicine systems were designed for use with ISDN-6 lines. As the obstetric department, neonatal unit and paediatric department were not adjacent to each other in the different hospitals, the configuration of the ISDN-line outlets and positioning of the monitors were tailored to meet local requirements.

Training in using the telemedicine equipment was provided by the equipment supplier and the telemedicine co-ordinator from the Royal Brompton. Project facilitators in the district hospitals assisted with the co-ordination of the teleconferences. The specialists provided advanced training in fetal heart scanning for senior sonographers from the district hospitals, and in echocardiography for the district paediatricians and neonatologists.

[#] The design of the project is fully described in Appendix B.

According to the established referral patterns to London specialist hospitals, pregnant women from the district hospitals were referred to three fetal medicine centres, babies were transferred to the Royal Brompton and to two other paediatric cardiology units, and older infants and children were referred primarily to the Royal Brompton or its outreach clinics. Thus the telemedicine service provided remote access to paediatric cardiologists based in the Royal Brompton and to a perinatal cardiologist who worked in one of the three fetal medicine centres. NHS ambulances transferred sick babies to, and from, London and the retrieval teams were usually from the receiving hospital.

Patients

Three patient groups in the district hospitals were eligible for teleconsultations.

i) Pregnant women referred for detailed ultrasound scans of the fetal heart;

ii) Newborn babies with a suspected heart problem;

iii) Older infants and children referred for a cardiac opinion. These patients normally were seen in the paediatric cardiology outreach clinics rather than in the specialist centre.

Eligible pregnant women were identified at the time of their anomaly ultrasound scan, which was usually performed at between 18 and 22 weeks gestation; the newborns were identified when admitted to the neonatal or special baby care unit; and the older infants and children were identified from the outreach clinic lists or from hospital correspondence. Babies and children who were not discharged immediately from specialist care were followed up for 3 to 12 months depending on the date when they first became eligible. Pregnant women were followed up until they were delivered.

Design of the evaluation

Fieldwork in the district hospitals began in May 2001 and the project facilitators identified all newly referred patients during three fieldwork phases: a 3-month baseline phase when the telemedicine equipment packages were installed in the four hospitals; a 6-month intervention phase when DGH2 and DGH3 randomised as intervention sites used the telemedicine referral service; and a 6-month service phase when all four hospitals used the telemedicine referral service. The project facilitators audited the hospital events experienced by the patients. Ethical approval was granted by a multi-centre research ethics committee and by appropriate local ethics committees.

The economic evaluation adopted a cost consequences approach from the dual viewpoints of NHS acute hospital services, and patients and their families. Patient consequences were assessed in two ways. Clinical outcomes after the patients' initial consultations were recorded. Postal surveys conducted over 10 months assessed the health-related quality of life of pregnant women and children following their initial consultation and again after 3 months.

a) Survey of pregnant women. The postal survey of women was confined to the two hospitals that customarily referred their patients to the perinatal cardiology service linked to the Royal Brompton Hospital. The women's questionnaires incorporated the Hospital Anxiety and Depression Scale (HADS) [Zigmond and Snaith, 1983] and the EQ-5D health status instrument. [Brooks, 1996] The HADS instrument assessed the women's levels of anxiety and depression in the past week, while the scales in the EQ-5D instrument applied to the women's health at the time of completing the questionnaire.

b) Survey of infants and children. For infants and children aged from 4 to 24 months, mothers completed an English translation of the French QUALIte de vie du Nourrisson (QUALIN) instrument. [Manificat et al, 1999 and 2000] For children aged from 25 months, mothers completed the Paediatric Quality of Life Questionnaire (PedsQL^{TM} Generic Core Scales version 4.0). [Varni et al, 2001 and 2002] The QUALIN instrument contains 33 statements, two-thirds indicating a favourable quality of life (e.g. This baby is happy, laughs or smiles easily) and a third suggesting a poorer quality (e.g. This baby cries as soon as he/she is left alone), and the statements are scored on a 5-point scale ranging from "definitely false" to "definitely true". A single overall score is obtained. The PedsQL^{TM} 4.0 instrument for young children identifies 21 activities (23 in the version for children over 5 years) that may have caused problems during the past month. These items are scored from 0 "never" to 4 "always". The items encompass 4 domains: physical functioning, emotional functioning, social functioning, and nursery / school functioning.

c) Family costs. Costs incurred by families when visiting a hospital locally or in London were assessed in the initial postal questionnaires. The questions covered mode of travel, journey distance, expenditure incurred, duration of journey and time spent in hospital, activities foregone, and any loss of earnings. [Bryan et al, 1995]

Costs to the NHS

Items of information on resource use events were entered in a specially designed audit database. The items covered hospital contacts related to the babies and childrens' presenting heart problems (outpatient attendances, inpatient admissions, ward attendances); women's antenatal attendances and prenatal admissions; clinical activities (diagnostic tests and investigations, surgical and non-invasive procedures, other treatments including cardiac drugs, total parenteral nutrition, and blood products); ambulance journeys; telemedicine consultations; and the status of NHS personnel who were consulted. A non-participant observational study was carried out in the outreach clinics of the district hospitals to estimate mean times for new and review attendances. Timings for the teleconsultations were obtained from pro forma completed by staff involved in the transmissions.

a) *Hospital unit costs.*[#] Finance departments in the district hospitals supplied unit costs including overheads at 2001-2 financial year prices for resource items incurred by the three patient groups, although they could not provide full sets of costs covering all items. The Royal Brompton Hospital and 2 fetal medicine centres supplied the unit costs for the specialist resource items. For the pharmaceutical items, one hospital pharmacy department priced the products and the itemised price list was circulated to the other pharmacy departments for confirmation. Weighted unit costs rather than mean costs were applied to all district items for which information had been supplied by two or more hospitals. The weights were derived according to the total referrals in each patient group for each hospital. [Longworth et al, 2003] (This approach was adopted because, firstly, there were wide variations in the numbers of referrals from the district hospitals (Table 1) and, secondly, inter-hospital differences existed in the submitted costs.) Where only a single cost was available for a resource item, that cost was applied.

Table 1: Summary of specialist referrals from the district hospitals over 15 months

All referrals to specialists over 15 months	District hospital			
	DGH1 N=77	DGH2 N=111	DGH3 N=147	DGH4 N=169
Pregnant women Newborn babies Older children	11 7 59	34 8 69	76 17 54	127 8 34
Telemedicine: Duration of access Referrals	 6 months 11 cases	 12 months 38 cases	 12 months 61 cases	 6 months 7 cases

b) *Telemedicine service costs.* Annual equivalent costs for the telemedicine equipment packages in the district hospitals, including installation of the ISDN-6 lines and VAT, were calculated, with an expected lifetime for the equipment of 5 years [Jacklin et al, 2003] and an annual discount rate of 3.5%. [HM Treasury, 2003] A mean equipment cost per patient was derived by dividing the annual equivalent cost for each hospital by the number of patients

[#] See Appendix C for further details on handling the NHS cost data, including the derivation of the weights.

referred via the telemedicine service (Table 1). Quarterly telephone bills covered ISDN-6 line rental, call charges and VAT. For DGH2 and DGH3, the bills over 12 months were pro rated, and for DGH1 and DGH4 the 6-month bills were pro rated. Time spent by the telemedicine co-ordinator visiting each hospital was also pro rated. Table 2 shows the mean costs per patient for the telemedicine service in the district hospitals.

Table 2: Mean cost per patient for the components of the telemedicine service in the district hospitals

Mean cost per telemedicine referral (£)	DGH1 (n=11)	DGH2 (n=38)	DGH3 (n=61)	DGH4 (n=7)
Telemedicine equipment	323.24	93.56	58.29	507.93
ISDN-6 line installation, and equipment maintenance contract	37.05	11.69	9.49	68.12
Training costs and support	23.94‡	12.04†	8.00†	36.20‡
ISDN line rental and call charges	35.17‡	77.00†	55.90†	21.65‡
Total mean cost per referred patient	519.40	194.29	131.68	833.90

† Costs and charges pro rated over 12 months;
‡ Costs and charges pro rated over 6 months.

c) *Other cost components*. NHS salary scales [DoH, 2002b-d] were used for costing hourly rates of staff time, as advised by Netten and Curtis [2002]. The hourly rates were pro rated according to the mean duration of time for completing the relevant tasks, including documenting patient records. NHS ambulance services provided costs for ambulances used for transferring babies and children, taking account of the distances travelled when making return journeys between each district hospital and a London hospital, and waiting times while at a hospital. [Leslie and Stephenson, 2003] DGH3, which had its own retrieval team, provided the costs for a neonatal transfer team, inclusive of travelling incubator, drugs, disposable items, and medical and nursing staff time. Since the distances between district hospitals and London varied by 30 miles, a weighted cost for an ambulance transfer was derived. Postcode data were used to calculate the distance of car journeys made by patients when attending hospital [Multimap, 2003], and motoring costs were applied to the mileage. [Automobile Association, 2003]

The derived mean costs per patient for the resource items are shown in Table 3 and Table 4.

Table 3: Resource items and costs applying to the initial consultation with a specialist

Resource item and mean times (minutes)	Telemedicine cost (£) and number of patients	Direct referral cost (£) and number of patients
Pregnant women	**N=52**	**N=196**
Ultrasound attendance	19.79 (n=4)	42.63 (n=196)
DGH clinician (5 min) Specialist (telemedicine 5 min; London 20 min) Co-ordinator (5 min) Specialist counselling (15 min)	3.12 (n=52) 3.23 (n=52) 1.17 (n=52) NA	NA 12.73 (n=196) NA 7.50 (n=39)
Newborn babies	**N=17**	**N=23**
DGH cot day Ventilated intensive care High dependency care Special care Paediatric ward	 690.60 (n=6) 441.14 (n= 3) 286.92 (n=6) 228.70 (n=2)	 690.60 (n=7) 441.14 (n=3) 286.92 (n=9) 228.70 (n=1)
Specialist cot day Neonatal intensive care	 1020.00 (n=1)	 1020.00 (n=15)
Specialist outpatient clinic	NA	118.00 (n=7)
DGH neonatologist (20 min) Specialist (20 min) Co-ordinator (20 min)	12.48 (n=17) 12.92 (n=17) 4.68 (n=17)	NA NA NA
Echocardiogram	18.25 (n=13)	18.25 DGH (n=4) 133.00 London (n=9)
Ambulance transfer	1476.23 (n=1)	1476.23 (n=18)
Older children	**N=48**	**N=168**
Outpatient attendance	128.45 (n=48)	128.00 outreach (n=10) 118.00 London (n=156)
DGH consultant (telemedicine 15 min; outreach 11.5 min) Specialist (telemedicine 15 min; outreach 11.5 min; London 9 min) Co-ordinator (15 min)	9.36 (n=48) 9.69 (n=48) 3.52 (n=48)	7.18 (n=156) 7.32 outreach (n=156) 5.73 London (n=10) NA
Echocardiogram	18.25 (n=42)	28.68 outreach (n=117) 18.25 DGH (n=11) 133.00 London (n=6)
Resting ECG	14.02 (n=25)	14.02 outreach (n=28) 45.80 London (n=1)
Chest x-ray	10.21 (n=16)	10.21 outreach (n=24) 22.00 London (n=1)
Specialist bed day	NA	631.00 (n= 2)

Table 4: Use of resources over 13 days following initial specialist consultation, with costs

Resource item and mean times (minutes)	Mean use per patient of resources		Unit cost or range (£)
	Telemedicine referral	Conventional referral	
Pregnant women	**N=52**	**N=196**	
Ultrasound attendance			
DGH	0.12	0.08	19.79
Specialist hospital	0.06	0.02	42.63
Specialist personnel (20 min)	0.06	0.02	12.73
Antenatal clinic attendance	0.25	0.36	36.00–47.71
Antenatal personnel (10.7–12.5 min)	0.25	0.36	2.33–7.80
Termination	0.04	0.05	644.01–883.00
Prenatal maternity bed day	0	0.03	185.27
Newborn babies	**N=17**	**N=23**	
DGH cot day (mean days/baby)			
Ventilated intensive care	2.06	0.02	690.60
High dependency care	0.79	0.22	441.14
Special care	2.71	1.78	286.92
Paediatric ward	1.41	0.13	228.70
Specialist cot day (mean days/ transferred baby)			
Neonatal intensive care	1.56	5.48	1020.00
Specialist outpatient clinic	0	0.01	118.00
Specialist (20 min)	0	0.01	12.92
Echocardiogram			
DGH	0.10	0.01	18.25
London	0.02	0.04	133.00
Ambulance transfer	0.02	0.03	1476.23
Older children	**N = 48**	**N = 168**	
Outpatient attendance			
DGH	0	0.04	128.45
Outreach	0	0.02	128.00
London	0.02	0.01	118.00
DGH paediatric consultant			
DGH outpatient clinic (17.5 min)	0	0.04	9.36
Outreach clinic (11.5 min)	0	0.02	9.36
Specialist			
Outreach (11.5 min)	0	0.02	7.32
London (9 min)	0	0.01	5.73
Echocardiograms			
DGH	0	0.01	18.25
Specialist	0	0.01	133.00
Paediatric inpatient day (mean days)			
DGH	0	0.03	281.16
Specialist hospital	0.19	0.02	631.00

Analytical perspective

A cohort approach was adopted for the economic analysis, whereby the mean costs of patients referred via telemedicine were compared with the mean costs of patients referred conventionally over the 15-month period. The original plan to undertake a comparative analysis between the pairs of randomised hospitals was set aside when the project design was modified to increase the telemedicine caseloads. (The telemedicine service was used infrequently by DGH2 and DGH3 during the first 4 months of the intervention phase, so the timetable for the project was extended and an additional fieldwork phase was introduced to allow all four hospitals to utilise the service.)

Analysis of variance (ANOVA), t tests, and chi-squared tests were used to explore differences between referral methods. All statistical tests were two sided. A p-value of ≤ 0.05 was considered to be statistically significant. As the distributions of the patient costs were skewed, bias adjusted non-parametric bootstrapping were performed, taking 5,000 iterations of the data, in order to generate confidence limits around the means. [Manly, 1997] The statistical computer packages of SPSS®, Stata Version 8, and S-PLUS were used for the analyses. [StataCorp, 2003; S-PLUS, 2000]

Three sets of mean costs per patient were generated: for the initial consultation with a specialist; for 14 days inclusive of the initial consultation; and for a maximum period of 6 months. Most of the pregnant women delivered their babies within the 6-month period, so the costs apply only to their antenatal care without prenatal inpatient admissions. A small number of pregnancies were terminated, and these events occurred within the first 14 days. Over half the newborn babies were discharged from hospital care by the end of the 14-day period. The older children were mainly assessed as outpatients, and the choice of a 6-month follow up period was in accordance with the evaluation of a virtual outreach referral service in London and Shropshire. [Jacklin et al, 2003]

Two cost analyses are presented. The first analysis compares the alternative referral methods for all patients, and for the three patient groups over the selected time periods. The second analysis focuses on the two hospitals that had access to the telemedicine service for 12 months, because the clinicians used the technology for different patient groups. DGH2 held teleconsultations for newborn babies and older children, while DGH3 used the telemedicine facilities for newborn babies and pregnant women. (Patterns of use of the telemedicine services for the separate patient groups have been fully analysed in three reports for the Department of Health that are available from the Brunel authors.)

Sensitivity analyses

Two scenarios are presented. The first takes account of travel costs incurred by women when attending a London hospital for a perinatal cardiology assessment. This sensitivity analysis was not extended to newborn babies because journeys to London for transferred babies were made by ambulance, nor to older children as the district hospitals were the venues for both the specialist outreach clinics and the teleconferencing sessions. The second sensitivity analysis considers the potential impact on patient costs when telemedicine facilities in a hospital are shared with other users.

Results

The district hospitals referred 504 eligible patients over 15 months and the telemedicine service was used for 117 (23.2%) of these referrals. Within the patient groups, the service was used for 52 (21.0%) of the 248 pregnant women, 17 (42.5%) of the 40 newborn babies, and 48 (22.2%) of the 216 older children. (Seven other babies were born in London obstetric units and transferred to paediatric cardiology centres after being diagnosed antenatally with severe congenital heart disease.)

The telemedicine referrals of pregnant women were from DGH3 only; telemedicine referrals of newborn babies were from DGH2 (6 babies), DGH3 (9 babies) and DGH4 (2 babies); and telemedicine referrals of older children were from DGH1 (11 children), DGH2 (32 children) and DGH4 (5 children).

During the months when the telemedicine service was available to the hospitals (Table 1), a total of 206 patients were referred from within the patient groups that the individual hospitals identified for the telemedicine service. Of these 206 patients, 117 (56.8%) were referred via teleconsultations.

Table 5: Demographic and clinical attributes of the referred patients

Demographic attribute	Referral method used		Test results
	Telemedicine	Conventional	
Pregnant women	**N = 52**	**N = 196**	
Mean age (SD)	28.7 (6.09)	32.1 (6.03)	t = 3.66 $p < 0.001$
Parity			
Primaparous	19 (36.5%)	52 (26.5%)	$\chi^2_1 = 2.01$ $p = 0.156$
Multiparous	33 (64.5%)	144 (73.5%)	
Type of pregnancy			
Singleton	52 (100.0%)	168 (85.7%)	$\chi^2_1 = 8.37$ $p = 0.004$
Multifetal	0	28 (14.3%)	
Fetal risk status			
Cardiac anomaly	41 (78.8%)	80 (40.8%)	$\chi^2_2 = 23.81$ $p < 0.001$
Down's syndrome	5 (9.6%)	57 (29.1%)	
Low risk	6 (11.5%)	59 (30.1%)	
Gestation at anomaly scan			
≤18 weeks	2 (3.8%)	39 (19.9%)	$\chi^2_2 = 12.89$ $p = 0.002$
19 – 21 weeks	42 (80.8%)	107 (54.6%)	
≥ 22 weeks	8 (15.4%)	50 (25.5%)	
Clinical circumstances			
Fetal screening	47 (90.4%)	159 (81.1%)	$\chi^2_1 = 2.51$ $p = 0.113$
Abnormal heart suspected	5 (9.6%)	37 (18.9%)	
Newborn babies	**N = 17**	**N = 23**	
Gender			
Male	10 (58.8%)	14 (60.9%)	$\chi^2_1 = 0.17$ $p = 0.896$
Female	7 (41.2%)	9 (39.1%)	
Birthweight			
≤1800 grams	5 (29.4%)	5 (21.7%)	$\chi^2_1 = 0.31$ $p = 0.580$
> 1800 grams	12 (70.6%)	18 (78.3%)	
Age when seen by specialist			
≤ 3 days	12 (70.6%)	10 (43.5%)	$\chi^2_2 = 5.74$ $p = 0.057$
4 – 10 days	0	6 (26.1%)	
≥ 11 days	5 (29.4%)	7 (30.4%)	
Heart symptoms			
Non-critical CHD suspected	8 (47.1%)	9 (39.1%)	$\chi^2_2 = 2.90$ $p = 0.234$
Critical CHD suspected	2 (11.8%)	8 (34.8%)	
Immature heart, other cardiovascular symptoms	7 (41.2%)	6 (26.1%)	
Older children	**N = 48**	**N = 168**	
Gender			
Male	26 (54.2%)	92 (54.8%)	$\chi^2_1 = 0.01$ $p = 0.942$
Female	22 (45.8%)	76 (45.2%)	
Mean age (SD)	4.4 (5.21)	5.1 (4.54)	t = 0.82 $p = 0.415$
Severity of symptoms and signs			
Normal	38 (79.2%)	114 (67.9%)	$\chi^2_3 = 3.70$ $p = 0.296$
Mild	6 (12.5%)	20 (11.9%)	
Moderate	3 (6.3%)	25 (14.9%)	
Severe	1 (2.1%)	9 (5.4%)	

Abbreviations: (SD) standard deviation; CHD congenital heart disease.

Demographic and clinical attributes (Table 5)

a) *Pregnant women.* Statistically significant differences were observed between pregnant women referred via telemedicine and those who travelled to London. The telemedicine women were younger by 3.4 years on average, no one was pregnant with twins, most (78.8%) had a greater than average risk of conceiving a fetus with congenital heart disease (CHD), and most (80.8%) underwent an anomaly scan at 19-21 weeks gestation. However, there was no significant difference in the clinical circumstances; the purpose of the great majority of referrals (90.4% telemedicine, 81.1% conventional) was to screen the fetus.

b) *Newborn babies.* A quarter of the newborn babies (29.4% of telemedicine referrals, 21.7% of London transfers) had a birthweight of 1800 grams or less. Although no statistically significant difference according to referral method was observed; 70.6% of the telemedicine babies were referred within the first 3 days of birth compared with 43.5% of the babies transferred to London. A third of the London transfers (34.8%) had symptoms suggestive of critical congenital heart disease; the rate for the telemedicine babies was 11.8%.

c) *Older children.* The children assessed via telemedicine were similar - in terms of gender, age distribution, and symptom severity - to the children who saw the specialists in outreach clinics or London. The mean ages were 4.4 years for telemedicine patients and 5.1 years for the directly assessed patients. Most patients were symptom-less (79.2% telemedicine, and 67.9% direct referrals, a non-significant difference).

Table 6: Outcome of specialist assessments of the referred patients

Outcome indicator	Referral method used		Test results
	Telemedicine	Conventional	
Pregnant women	**N=52**	**N=196**	
Prenatal fetal diagnosis Severe or moderately severe CHD	4 (7.7%)	33 (16.8%)	χ_1^2 = 2.71 p = 0.100
Newborn babies	**N=17**	**N=23**	
Outcome of specialist assessment			
Manage in DGH with possible return to cardiac centre	15 (88.2%)	9 (39.1%)	
Medical care in cardiac centre	1 (5.9%)	9 (39.1%)	χ_2^2 = 9.89 p = 0.007
Emergency care in cardiac centre	1 (5.9%)	5 (21.7%)	
Older children	**N=48**	**N=168**	
Diagnostic assessment			
Murmur – normal or self-correcting	36 (75.0%)	103 (61.3%)	
Murmur – severe or moderately severe	4 (8.3%)	23 (13.7%)	χ_2^2 = 3.06 p = 0.216
Other cardiovascular cases	8 (16.7%)	42 (25.0%)	
Outcome of specialist assessment			
Discharged	20 (41.7%)	75 (44.6%)	
Review in due course	22 (45.8%	59 (35.1%)	
Early investigation or reassessment	4 (8.3%)	17 (10.1%)	χ_4^2 = 2.85 p = 0.584
Intervention planned	1 (2.1%)	9 (5.4%)	
Immediate admission to cardiac centre	1 (2.1%)	8 (4.8%)	

Abbreviations: CHD congenital heart disease; DGH district general hospital

Outcome of the specialist assessment (Table 6)

a) *Pregnant women.* For 15% (37/248) of all referred women, a fetal diagnosis of severe or moderately severe congenital heart disease was made. There was no statistically significant difference in the proportions of telemedicine women and London referred women diagnosed in this way.

b) Newborn babies. Patterns of care following assessment of the newborn babies by the specialists were significantly different for the alternative referral methods. Fifteen (88.2%) of the 17 babies assessed via telemedicine continued to receive their care in the district neonatal units and 2 were transferred to London. Among the 23 babies transferred directly to a cardiac centre, 9 (39.1%) were returned to their referring hospital for medical management and 14 remained in London (p=0.007).

c) Older children. Three-quarters of the older infants and children (76.9%, 166/216) were assessed for heart murmurs, most of which were normal or self-correcting. There was no statistically significant difference in the specialist management strategies for the alternative referral methods; for instance, 41.7% of the telemedicine patients and 44.6% of the clinic attenders were discharged immediately.

Health related quality of life assessments[#]

a) Pregnant women. Questionnaires were sent to 63 women in DGH1 and DGH3 during the 10-month survey and replies were received from 37 (58.7%): 26 from 43 women assessed via telemedicine and 11 from 20 women who travelled to London. No statistically significant differences were observed between the two groups of respondents in their mean scores for the anxiety and depression scales and the rating of their health on the EQ-5D visual analogue scale. However, the EQ-5D tariffs for the London travellers, derived from five statements on mobility, self-care, usual activities, pain and discomfort, and anxiety and depression, were significantly lower, the mean (standard deviation (SD)) and median tariffs being 0.72 (0.22) and 0.76 for London women, and 0.86 (0.14) and 0.83 for telemedicine women (Kruskal Wallis χ_1^2=4.64, p=0.031). Twenty-five women (67.6%) completed a 3-month follow-up questionnaire, but as only 12 responded before they gave birth, the responses were too few for meaningful comparisons to be drawn.

b) *Infants and children*. Parents of 154 children aged from 4 months were sent a questionnaire a fortnight after their child's consultation with a specialist either in a clinic or as a teleconsultation, and 58 (37.7%) were completed. The mean (SD) and median ages were: 6.4 (5.8) and 4 years for 12 telemedicine children, and 5.3 (4.6) and 4 years for 46 clinic attenders. Telemedicine patients experienced a slightly better quality of life, both the children under 2 years for whom the QUALIN instrument was completed, and the older children who had been assessed by the PedsQL™ instrument. The 3-month follow-up survey indicated that the quality of life of almost all the children had improved.

NHS costs

Table 7 presents the bootstrapped mean costs and 95% confidence limits (CL) for all telemedicine patients and patients referred conventionally and for the 3 types of patients:

[#] Detailed analyses of the quality of life assessments for the women and children are presented in Appendix D.

pregnant women, newborn babies, and older children.[#]

a) Initial consultation costs. The bootstrapped mean NHS cost for the initial consultation with a specialist for all 117 patients using the telemedicine service was £411 (95% CL £352 to £481). The comparative cost for the 387 conventional referrals was lower at £277 (95% CL £212 to £389). However, the t test, which was applied the non-bootstrapped means, was not statistically significant. Usage patterns of the key non-telemedicine resource items applying to the initial consultation are shown alongside the costs in Table 3.

Table 7: Bootstrapped mean cost per patient for telemedicine and conventional referrals over three time periods

Referral method		Time period		
		Initial consultation	14 days	6 months
All referred patients				
Telemedicine N=117	Mean (SD) 95% CL	£411 (£355) £352 to £481	£1,437 (£3,753) £888 to £2,305	£3,350 (£9,725) £2,035 to £6,020
Conventional N=387	Mean (SD) 95% CL	£277 (£862) £212 to £389	£863 (£3,329) £582 to £1,269	£2,172 (£6,736) £1,670 to £3,132
Test result		t = -1.61, p=0.107	t= -1.58, p=0.114	t= -1.48, p=0.141
Pregnant women				
Telemedicine N=52	Mean (SD) 95% CL	£143 (£11) £141 to £147	£190 (£162) £159 to £263	£925 (£539) £800 to £1,097
Conventional N=196	Mean (SD) 95% CL	£59 (£11) £58 to £61	£167 (£372) £128 to £238	£714 (£728) £632 to £849
Test result		t= -47.73, p<0.001	t= -0.43, p=0.668	t= -1.95, p=0.052
Newborn babies				
Telemedicine N=17	Mean (SD) 95% CL	£917 (£465) £755 to £1,237	£6,962 (£7,018) £4,019 to £10,671	£17,121 (£20,937) £9,401 to £30,776
Conventional N=23	Mean (SD) 95% CL	£2,449 (£2,323) £1,782 to £4,009	£11,206 (£8,378) £7,771 to £14,532	£20,156 (£18,066) £14,292 to £30,040
Test result		t= 2.65, p=0.012	t= 1.69, p=0.099	t= 0.49, p=0.624
Older children				
Telemedicine N=48	Mean (SD) 95% CL	£523 (£245) £463 to £604	£834 (£2,255) £487 to £2,187	£1,103 (£2,721) £554 to £2,388
Conventional N=168	Mean (SD) 95% CL	£235 (£556) £175 to £377	£265 (£620) £199 to £420	£1,423 (£3,575) £959 to £2,062
Test result		t= 3.49, p=0.001	t= -2.91, p=0.004	t= 0.57, p=0.572

Note: Statistical tests were performed on non-bootstrapped mean costs.

The telemedicine referral option was significantly more costly for pregnant women, but most of the cost differential was attributable to the technology and its operating costs in DGH3 of £131.68 per referral (see Table 2). For most telemedicine women the itemised resource

[#] Box plots of the observed patient costs are presented in Appendix E.

costs on the day of the remote consultation totalled £7.50, because the women were not scanned during the teleconferencing sessions. Rather, videoed ultrasound recordings had been made when they underwent their routine anomaly scan in the obstetric department and the pre-recorded images were transmitted during the link-ups with the specialist. The telemedicine referral option was also significantly more costly for older children, although the basic costs of a hospital attendance and medical staff time for the alternative referral methods were similar. For the newborn babies, in contrast, the telemedicine referral option was significantly cheaper because only 1 telemedicine baby was transferred by ambulance to London the same day and admitted to a specialist neonatal intensive care cot. For newborn babies who were transferred to, and from London, the costs for each cot-day were apportioned according to the hours spent in the district and specialist units.

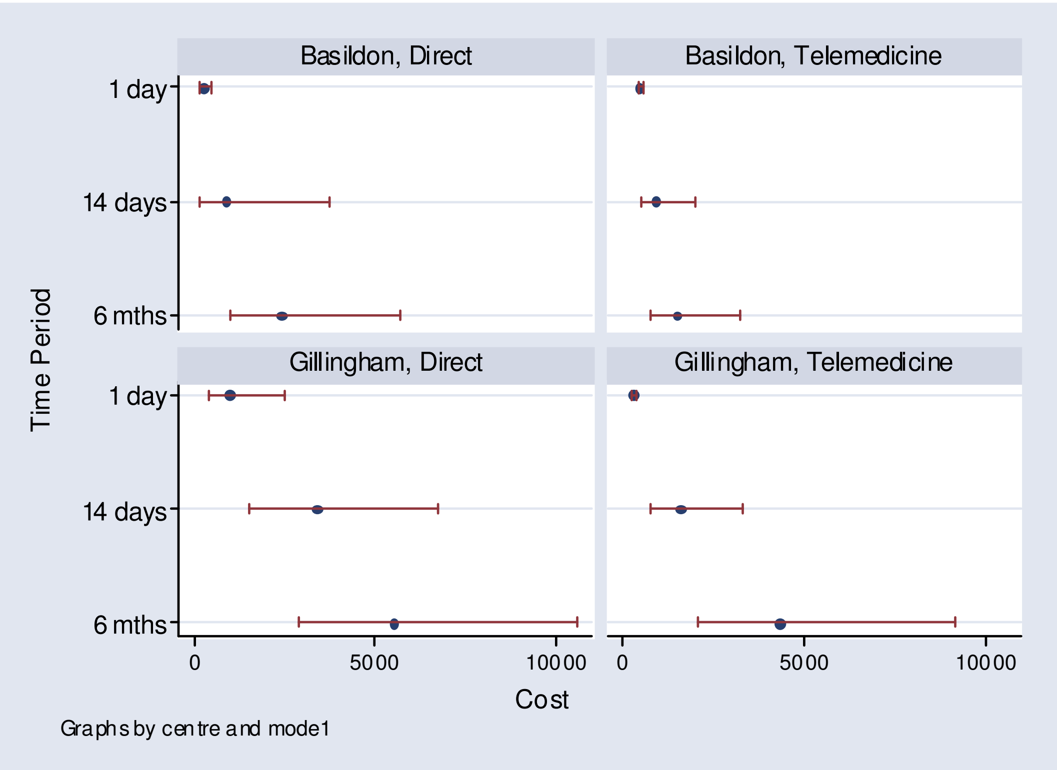
b) *14-day costs.* The disparity between the bootstrapped mean cost per patient for all telemedicine referrals versus all conventional referrals widened to £574 over the 14-day period inclusive of the initial consultation, but the difference was still not statistically significant. Table 4 shows the usage rates for the key non-telemedicine resources in the 13 days following the consultation.

The comparative 14-day mean costs for the pregnant women were relatively similar. Termination of pregnancy was the most costly resource item, but as few terminations were undertaken in both the telemedicine and London cohorts of patients, the impact of these events on the overall mean costs was limited. For the newborn babies, a specialist intensive care cot day of £1,020 was the most costly hospital item (see Table 4). The London-referred babies spent an average of 5½ days receiving specialist care in the 13 days following their transfer to London compared with 1½ days of specialist care for the telemedicine transferees. Consequently, the mean cost per baby over 14 days for the telemedicine cohort was considerably lower, although the cost differential was not statistically significant.

The mean 14-day cost for the telemedicine group of older children was significantly higher than the comparative cost for the outpatient clinic attenders even though almost 90% of the children assessed via telemedicine were either discharged after the initial consultation or booked for a review appointment at a later date (see Table 6). This situation arose because an outlier in the telemedicine cohort received emergency treatment in excess of £15,000 over the 14-day period.

c) *6-month maximum costs.* After six months of follow up, once again there was no statistically significant difference in the mean costs for all patients referred either via telemedicine or conventionally. For newborn babies, and older children, likewise, there was no significant difference in the mean costs, with telemedicine being the cheaper option for both groups (Table 7). However, antenatal care incorporating a teleconsultation was dearer than care involving a visit to London (£925 (95% CL £800 to £1,097) v £714 (95% CL £632 to £849), (p=0.052). The cost differential was mainly attributable to local variations in the delivery of maternal care. The telemedicine cases were from DGH3 and all women referred from this hospital made an average of 10 antenatal visits to district clinics during the later months of their pregnancies compared with an average of 5 visits for the women referred from the other three hospitals. When the women in DGH3 alone were considered, the bootstrapped mean costs for antenatal care were higher: £925 (95% CL £800 to £1,097) for the telemedicine referrals and £784 (95% CL £638 to £981) for the London referrals.

Figure I: Bootstrapped mean cost per patient for two hospitals: DGH2 covering newborn babies and older children, and DGH3 covering pregnant women and newborn babies (CR = conventional referral; TM = telemedicine referral)



Telemedicine service costs in district hospitals[#]

The telemedicine facilities were used for newborn babies and older children in DGH2 and for newborn babies and pregnant women in DGH3, and the relative magnitude of the mean

[#] Mean costs per patient for the two hospitals and box plots of the observed patient costs are in Appendix E.

patient costs for the alternative referral options can be seen in Figure I. In each hospital after 6-months follow up, the mean cost per telemedicine referral from the two patient groups combined was lower than the mean cost for patients from these combined groups who were referred conventionally. However, the cost difference within each hospital was not statistically significant.

The higher overall six-month costs for DGH3, illustrated in Figure I, were attributable to case severity among the newborn babies in the regional intensive care unit. After being assessed for a heart problem within the first fortnight of life, the babies often remained in the unit for weeks, especially those with a very low birthweight. Thus, there were 8 babies in DGH3 whose total costs over 6 months lay between £20,000 and £70,000, compared with only 2 babies in DGH2 whose 6-month costs lay between £20,000 and £30,000.

Family costs

a) *Pregnant women.* Costs of visits by women to London hospitals were provided in 6 questionnaires, while 26 questionnaires included details of visits to DGH3 by women whose videoed anomaly scans were transmitted to London. The return journeys to London were made either by car or train and the mean distance was 100 (SD 28) miles. Visits to DGH3 were mostly made by car (88%), and the mean mileage for the return journeys was 9 (SD 9) miles. Five (83%) of the London women were accompanied by another adult; likewise, 22 (69%) of the women attending the local hospital. Only 2 women or their companions experienced a loss of earnings. The median costs of the hospital visits, inclusive of travel, any loss of income, and incidental expenses, were £50.36 (IQR £38.00 to £77.20) for travellers to London and £12.59 for women attending DGH3 (IQR £2.52 to £15.60) (Kruskal Wallis χ_1^2 = 9.25, p=0.002). Visits to the local hospital were mostly completed within 2½ hours compared with 5½ hours for the London visits.

b) *Infants and children.* Details of family expenditure were provided in the questionnaires from parents whose child attended a district hospital for either an outreach clinic appointment or a teleconsultation. Cars were used for 86% of journeys. Total costs for the telemedicine and non-telemedicine families were similar - median £8 (IQR £5 to £12), and £6 (IQR £3 to £16) respectively. A median of 1½ hours was spent in hospital by both groups of families.

Sensitivity analysis[#]

a) *Women's travel to London.* This sensitivity analysis took account of the travel costs incurred by women from DGH3 when attending a London hospital for assessment or the local hospital for an ultrasound scan that was recorded and later transmitted to London. As the patient survey covered only 10 of the 15 fieldwork months, travel details were not available for 57% of the 76 women, so estimates of travel costs for the other women were obtained by multiple imputation. [Rubin, 1987; Schafler, 1997] Initial consultations conducted remotely remained the more costly referral strategy, the bootstrapped mean costs per patient being £149 (95% CL £146 to £152) for teleconsultations and £91 (95% CL £83 to £101) for London visits ($t=-15.03$, $p<0.001$).

b) *Shared use of teleconferencing facilities.* The teleconferencing equipment supplied to DGH1, a control hospital, was installed in a central suite where it was accessible to other users. In 2004-05, the telemedicine suite was being used once or twice a week for cancer network teleconferences, with approximately 10 patients discussed during each session. So in this sensitivity analysis, the costs of the telemedicine service in DGH1 were shared among the 11 observed cardiac users and 300 cancer patients (the estimated number of cases reviewed during 30 cancer teleconferences over 6 months). After adding the charges for the cancer network telephone calls to the observed costs of the telemedicine services, the re-attributed mean cost per patient, based on 311 telemedicine cases, was £18.94. According to this scenario of shared usage, the bootstrapped mean cost for the initial consultations of the 11 cardiac patients, all of whom were children, was now slightly lower than the mean cost for the 48 children seen directly by the specialists (£240 (95% CL £178 to £515) vs £268 (95% CL £168 to £712) ($t=0.12$, $p=0.901$)).

Discussion

Evaluating a telecommunications technology

The economic evaluation of the telemedicine service operated by the Royal Brompton Hospital in London was formally designed with two district hospitals randomised as intervention sites and two hospitals acting as control sites. The consultants in each hospital decided how the telemedicine service would be utilised: which patients to refer, and the preferred method of conducting remote consultations – by having the patient present or by transmitting pre-recorded ultrasound images. The project supplied the telemedicine equipment packages and the hospitals incurred the costs of the ISDN-6 line rental and telephone calls. However, uptake of the service in the intervention hospitals was slower than

[#] Tables presenting the cost results for the sensitivity analysis scenarios are included in Appendix F.

anticipated and the project design was modified to allow all four hospitals to be studied while using the service. The delays in advancing the project may have been a function of the type of technology under evaluation – telehealthcare. Williams and colleagues have observed that, for the most part, evaluations conducted within the broader ambit of health technology assessment cover innovations that are stable and can rely on well established and validated forms of measurement, as applied in randomised controlled trials and case controlled studies. With teleheathcare, however, the emergent nature of these systems and their uncertain impact on organisational and professional structures "mean that evaluation is not self-evident, but that it demands mapping in ways that construct an alternative to the conventional model of biomedical research". [Williams et al, 2003, p53]

Information on referral patterns between the secondary and tertiary hospital sectors of unborn babies, neonates and older children for cardiological assessment was not available when the project was planned, so details were collected on all relevant referrals from the four hospitals over 15 months. This approach revealed wide inter-hospital variations in referral numbers, even though the hospitals were similar in terms of their annual caseloads of maternal deliveries, which exceeded 3,100 per annum. For the primary analysis, a cohort approach was adopted whereby the attributes and costs of all patients referred via the telemedicine service were compared with all patients referred conventionally. Although no statistically significant difference in the presenting clinical circumstances was observed (Table 5), telemedicine patients were generally in a better state of health. Among the referred women, 20% of the cohort referred directly to London had a suspected fetal heart anomaly compared with only 10% of the telemedicine cohort. Among the newborn babies, 35% of the London transfers had symptoms suggestive of critical congenital heart disease compared with 12% of the telemedicine cases. Finally, the proportion of infants and children experiencing heart symptoms was higher in the cohort seen in the outreach clinics or London (32%) than in the cohort assessed remotely (21%).

The patient cost results over six months also indicated that the telemedicine cohorts had lower utilisation levels of NHS hospital resources, although not significantly so, than the conventionally referred cohorts. The 6-month mean costs for newborn babies, and infants and children in Table 7 favoured the telemedicine referrals. In the only hospital to use the telemedicine service for perinatal referrals, the mean cost per woman for antenatal care favoured the conventional group.

These equivocal 6-month cost results may be set beside the results from an evaluation of a telemedicine outpatient referral service between primary and secondary care in which the telemedicine patient costs were significantly greater after six months. The 'virtual outreach' service linked family doctors in 29 general practices with consultants in eight specialties in two English hospitals. Remote consultations were held in the doctors' surgeries using personal computer-based technology and ISDN-2 telephone links. The comparator consultations were held in the hospitals' outpatient clinics. [Wallace et al, 2002] The 6-month mean costs for resource events associated with the presenting condition were £393 per patient in the virtual outreach group and £286 per patient in the standard outpatient group (P<0.0001), with the difference being attributed to the excess cost of the initial teleconsultation. [Jacklin et al, 2003] However, strict comparisons cannot be drawn between the two studies. The technical configuration of the telemedicine systems differed, and the virtual outreach costings covered both primary care and hospital resource use during the 6-month follow up period. More importantly, however, the patient groups differed: the virtual outreach study excluded emergency referrals and the participating patients were randomised between the two arms [Wallace et al, 2004], whereas this project prospectively audited all emergency and routine referrals, and decisions on the methods of referral were left to the referring clinicians.

Virtual outreach patients were offered a follow up hospital appointment more often than the hospital outpatient attenders (52% v 41%, P<0.0001), particularly in the surgical specialties of orthopaedics, and ear, nose and throat [Jacklin et al, 2003], unlike in this project where the re-booking rates for infants and children were similar for telemedicine patients (58%, 28/48) and comparator patients (55%, 93/168). The different specifications of the video conferencing systems used in the two evaluations may have been a contributing factor. For this single specialty-project, the equipment packages were designed specifically to transmit cardiac ultrasound images for diagnostic purposes over ISDN-6 telephone lines. Heart sounds could also be transmitted, since the hospitals were equipped with electronic stethoscope senders.

The transmission of skilfully performed echocardiograms is essential in telecardiology. The project relied on the district paediatric departments having access to a suitable echocardiography machine. The district paediatricians and neonatologists were offered advanced echocardiography training. (Improvements in the echocardiography skills of paediatricians are seen as an educational benefit arising from paediatric telecardiology. [Casey, 1999]) Obstetric sonographers also received advanced tuition on screening for fetal heart anomalies. Timetabling the paediatric training sessions was delayed and one hospital needed to purchase a paediatric echocardiography machine. These factors contributed to the slow uptake of the telemedicine service.

Equivalent annual costs of the video conferencing systems and annual telecommunication charges (ISDN rental and call charges) were key resource components in both the virtual outreach project and this evaluation, while the key variable for assigning these costs to individual patients was the number of consultations conducted using the systems. [Jacklin et al, 2003] The telemedicine components cost per patient ranged from £834 in DGH4 where 7 tele-referrals were made over 6 months, to £132 in DGH3 with a caseload of 61 tele-referrals over 12 months (Table 2). However, the extent to which the mean cost for the technology impacted on the overall mean cost for an individual hospital depended upon the casemix of cardiac patients being referred in this manner. For ambulatory patients (child outpatients or pregnant women), telemedicine initial consultations were more costly. With very ill babies, the converse applied: transferring a baby by ambulance to a specialist centre at mean cost of £1,476 was a far more expensive strategy. So, for DGH3, whose tele-referral caseload consisted of 52 ambulatory women and 9 neonates, the telemedicine service was the cheaper option both for initial consultations (£260 (95% CL £198 to £390) vs £982 (95% CL £439 to £2,486)) ($t=2.33$, $p=0.022$), and after 6 months of follow up (Figure 1). Sharing the technology with other users in DGH1 radically reduced the original mean teleconsultation cost for a child from £740 to £240, a value that was slightly lower than the mean cost for a conventional consultation. But the volume of additional users needed to achieve this target cost was 300 in 6 months.

For the surveyed parents, the telemedicine service had two commanding attributes. It could reduce appointment waiting times for children referred for screening, and district paediatricians could use the technology for patients they were particularly concerned about, thus minimising the need for children to travel to London. With respect to the technology itself, the evidence from our survey (see Appendix J) and the virtual outreach project [Wallace et al, 2002] showed that patients and parents found remote consultations to be an acceptable mode for obtaining advice as long as technical problems did not arise.

Discussions held in the district hospitals after the completion of the fieldwork (see Appendix K) revealed that the clinicians found learning to use the telemedicine system was less problematic and time consuming than updating their skills or acquiring sufficient expertise in scanning the heart for remote transmission and diagnosis. They stressed the importance of having mutual trust and professional respect between the specialists and the district staff; collaboration would be more successful if the staff had already worked together (for instance, in outreach clinics) before a telemedicine service was introduced. There had been some teething problems when the technology was first used, but as the project involved an experienced telemedicine coordinator, the problems were rapidly resolved. However, easy, and safe, access to the telemedicine equipment within the paediatric or obstetric department was an important incentive to using the service. It was desirable also that there was always a person on duty in the specialist centre who was familiar with the technology and could facilitate an emergency teleconsultation, even though these occasions occurred infrequently. The ongoing costs associated with the ISDN-6 lines (rental and call charges) and renewal of the equipment maintenance contract from already tight budgets were a concern for the business managers.

Implications for telemedicine in the NHS

The role adopted for the paediatric telemedicine service in the district hospitals was to supplement, rather than substitute, existing services provided by specialists from the Royal Brompton Hospital. The three hospitals that used the service for paediatric referrals continued to host paediatric cardiology outreach clinics at 3 or 4 monthly intervals, and in the hospital that did not use the service for this purpose, the pattern of monthly outreach clinics was unchanged. The perinatal telemedicine service also complemented existing tertiary screening services, although only one hospital made use of the technology. For babies and children with moderate or severe symptoms, the telemedicine service facilitated rapid access to the Brompton specialists for advice, thus avoiding in many cases ambulance transfers to the Royal Brompton or to another London cardiac centre with a vacant cot or bed.

By allowing the district clinicians, in collaboration with the Royal Brompton specialists, to determine the roles for the telemedicine service, the hospitals' use of the service became embedded in routine practice. All four hospitals were still holding teleconferencing sessions with Royal Brompton specialists three years after the project's fieldwork programme ended. May and colleagues, from studying teledermatology innovations in the NHS, identified key features of telemedicine services that become 'normalised': i) they emerge out of service reconfiguration rather than experimental research; ii) monitoring is characterised by audit rather than evaluation; iii) they permit the front end provider (in our case district clinicians) a degree of flexibility and autonomy in the use of the hardware; (iv) they are viewed as adjuncts to existing 'traditional' services; and (v) they become part of routine service delivery. [May et al, 2005]

May and colleagues concluded from their studies that telemedicine as an innovation in the NHS was 'disappearing', partly because initiators underestimated the organisational complexity in achieving a workable telemedicine service that extended well beyond the development and evaluation of hardware. [ibid] However, after reviewing evidence on the use of new medical technologies within the NHS, the House of Commons Health Committee was more positive and recommended that trusts be encouraged to identify 'clinical champions' to promote the benefits of telemedicine and ensure that the organisation and staff development requirements to make the system workable are in place. [House of Commons Health Committee, 2005] The Committee believed that adoption of the technology could be driven forward by the Government's target for the NHS that, by 2008, no one will wait more than 18 weeks from referral by a general practitioner to hospital treatment. [DoH, 2004a] However, the introduction of the 'payment by results' financial system, which by 2008/09 will cover outpatient care, could act as a disincentive if delays occur in adjusting mandatory tariffs to reflect the true cost of care facilitated by new technologies. The deferred 2005/06 tariffs for paediatric cardiology are a case in point. [DoH, 2004b] The published tariff of £192 for a first outpatient attendance is comparable to this project's weighted mean cost per child of £195 for an outreach first clinic attendance (inclusive of outpatient unit cost with overheads, medical staff time, an echocardiogram, a resting ECG and a chest x-ray). However, the cost of a child's teleconsultation was £388 in the hospital that made the greatest use of the paediatric telemedicine service, the excess cost being attributable to the telemedicine components.

Telecommunication costs (i.e. ISDN line rental and call charges) formed between 40% and 50% of the technology cost per patient in both the virtual outreach project and in the two hospitals that used the Royal Brompton telemedicine service over 12 months. The UK's largest telephone company was the service provider. N3, the new national information technology network for the NHS, will allow individual sites to access a combination of broadband connections and network services, and it will facilitate fast electronic transmission of visual data (such as video and x-ray images) and video conferencing. [DoH, 2004c] Whilst N3 promises substantial savings on the telephone bills of NHS organisations, it is too early to clarify its potential for supporting telemedicine services by meeting technical standards, offering timely access, and ensuring reliability of video conferencing transmissions. Video conferencing equipment packages are the other major technology cost, but, from recent experience of upgrading the video conferencing system in the Royal Brompton Hospital, it is doubtful whether benefits from technology price changes will be quickly realised, unless NHS purchasing can take advantage of economies of scale.

Implications for paediatric and perinatal cardiology

The small tertiary specialty of paediatric cardiology is facing escalating workload pressures, even though the annual rate of children born with congenital heart disease is forecasted to rise only slightly as the birth rate rises. [DoH, 2003a] In England, in September 2004, the specialty had a staff of 63 consultant paediatric and perinatal cardiologists (compared with 1,839 consultant paediatricians from whom most cardiac referrals are received) and 23 specialist registrars in training programmes of 5 years duration. [DoH, 2005] These cardiologists were based in 12 regional paediatric congenital heart disease units. Most units operated a system of paediatric outreach clinics; the Royal Brompton Hospital, for instance, has a network of clinics in 37 hospitals. Children attending outreach clinics include new referrals for diagnosis, and review patients who are being monitored either prior to, or following treatment, and the numbers of review patients are steadily increasing as more and more children with congenital heart disease survive into adulthood. The Paediatric and Congenital Cardiac Services Review Group recently recommended that in order to minimise the 'patient journey', all units should hold peripheral outreach clinics in premises with suitable echocardiography facilities, and some rationalisation of existing outreach services may be required. [DoH, 2003a] However, any rationalisation process would need to take account of both the journey times for the specialists travelling between the main unit and the peripheral sites and the frequencies of the scheduled clinic sessions at each site (e.g. monthly or 3-monthly). Incorporating additional half-day outreach clinic sessions in the job plans of paediatric cardiologists could prove to be difficult to negotiate.

Tertiary perinatal cardiology services mostly follow a 'hub and spoke' model, with a paediatric cardiac unit as the hub and perinatal medicine centres as the spokes. The numbers of spokes vary from one, as in Birmingham, to as many as five, as in a London service provided by the Royal Brompton Hospital. The model represents best practice, because it permits comprehensive assessment of affected fetuses by a variety of fetal specialists working together. [Gardiner, 2001] However, the great majority of women referred for fetal heart assessment have a normal fetus – in the West Midlands fetal medicine centre [Kilby and Higgs, 2001] and in a centre linked to the Royal Brompton the rates for normal hearts in recent audits of cardiac referrals were 80% and 73% respectively. Another factor to consider is that fetal medicine referrals in general are seen very promptly; the interval between a scan being performed in an obstetric unit and the woman being seen at a referral unit was less than 2 working days in 45% of English obstetric departments in 2002. [UK National Screening Committee, 2005] Concerted efforts in raising standards of antenatal screening in district maternity services are being made [Harcombe and Fairgrieve, 2004], with improved fetal heart ultrasound seen as a priority since marked regional variations exist in the practice of visualising cardiac outflow tracts during second trimester anomaly scans. [UK National Screening Committee, 2005] Higher detection rates of equivocal and unequivocal cardiac anomalies by sonographers in maternity units will lead, in turn, to higher rates of referral for specialist fetal echocardiography.

Our research found that in the area of neonatal care, when faced with a critically ill baby, paediatricians or neonataologists in the district neonatal units were most likely to arrange an emergency transfer rather than a teleconsultation, probably because they felt that a transfer was inevitable and they did not wish to cause any delay. The doctors relied on the technology for problem solving; that is, when they were uncertain about the diagnosis of a heart problem or the continued management of a baby who was failing to thrive. For instance, a third of the 40 referred babies suffered from a failure of the patent arterial duct in the heart to close, or from persistent pulmonary hypertension of the newborn, or from abnormal heart rhythms. Teleconsultations were held for 7 of these 13 babies and only 1 was transferred (as a planned day case for ligation of the patent duct).

Neonatal telemedicine services could complement current services in other ways. In Greater London, for example, introducing remote links between the three paediatric cardiology units and the neonatal care units in the teaching hospitals and larger general hospitals would reduce the occasions when paediatric cardiology trainees are asked to make an emergency visit to assess a newborn's heart, especially as the European Working Time Directive has curtailed the amount of time that doctors in training can spend on clinical duties outside normal working hours. In England, as part of a Government strategy for raising standards for neonatal care [DoH 2003e], 24 managed clinical networks covering local geographical areas have been set up and they usually incorporate 6 to 10 hospitals with special care baby units, high dependency care units, and one or two neonatal intensive care units. As the networks become fully operational, they will, presumably, liaise closely with their neonatal cardiology service, and if concerns are raised about standards of care for babies with heart problems, consideration could be given to introducing remote diagnostic facilities via telemedicine.

Northern Ireland and Scotland already have telemedicine networks of this kind in operation. The Irish network for neonatal care links the paediatric cardiology unit in the Royal Belfast Hospital for Sick Children with neonatal units in three district hospitals. The service was originally established in the 1990s [Casey et al, 1996, Mullholland et al, 1999] and used primarily for the remote diagnosis (or exclusion) of congenital heart disease in neonates. During 2005, however, it was being extended to permit the assessment of murmurs in older children. [Dr Brian Grant, personal communication, 2005] The Scottish Paediatric Telemedicine Network is more recent in origin and covers neonates and older children. With funding from the Scottish Executive Health Department's Telemedicine Initiative, the network was set up as a pilot involving five hospitals in 2004 and has been rolling out during 2005 to a further five or more sites. The network is linking paediatricians in district hospitals with paediatric cardiologists in Glasgow, Edinburgh and Aberdeen, paediatric surgeons in

Glasgow and to other tertiary specialties (e.g. child and adolescent psychiatry). [Hazel Archer, personal communication, 2005] The videoconferencing equipment used in both networks is similar to that provided by our project, and remote link ups in both networks are usually via ISDN-6 telephone lines.

The way forward

For NHS commissioning purposes, paediatric cardiothoracic services for the fetus, neonate, infant, child and adolescent with heart disease are activities covered by the specialised services national definitions set. [DoH, 2003b] Commissioning of specialised services is undertaken by local specialised commissioning groups on behalf of consortia of primary care trusts, and in England, in mid 2005, there were 26 groups. The groups have dedicated commissioning teams consisting of commissioners, public health advisers and finance and information staff. [House of Lords Hansard, 2005] The national guidance for commissioning specialised paediatric services distinguishes between care provided in specialist centres and care provided in other settings. "The costs incurred by specialist centres in providing outreach services will be regarded as specialised but the costs incurred by local services in hosting outreach clinics will not be regarded as specialised." [DoH, 2003c] The guidance implies, therefore, that the financial responsibility for telemedicine services in district hospitals ultimately lies with local primary care trusts as commissioners of secondary care. [DoH, 2003d]

The telemedicine service covered by this economic evaluation is an exemplar in the field of paediatric and perinatal cardiology. The evaluation has provided insights into the different roles adopted for the service in four district hospitals and identified factors that promoted, and hindered, the uptake of the technology; the work has produced robust estimates of referral caseloads and, through the application of logistic regression modelling, identified key variables for predicting telemedicine caseloads in district hospitals elsewhere (see Appendices G and H and the three earlier project reports). Finally, and, most importantly, the research has found that operating a telemedicine service alongside conventional referral services can be cost neutral in the longer term.

In the intervening years between commissioning the project and reporting its findings, the focus of the Government's reform of the NHS has moved further towards improving the quality of care for patients, with improved access to services (the 18-week maximum wait from referral to hospital treatment by 2008) being a national target. Primary care trusts have local delivery plans for the financial period, 2005/6 to 2007/8, detailing how local and national priorities and targets will be met within available resources, and the plans should cover specialised services commissioned by their local specialised commissioning group. The groups' commissioning teams, in turn, negotiate with their specialist service providers, especially, in our case, the regional units for paediatric cardiology. These teams should be in an advantageous position, therefore, to assess, firstly, the potential for operating a paediatric telecardiology service within their network of primary care trusts, and secondly, whether a clinical champion can be identified to promote the service both within the specialist unit and in the hospitals that would form the spokes of the service. Comprehensive guidance on implementing such services and the resource consequences is contained in the four reports from this project.

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EPILOGUE

EPILOGUE

In the summer of 2005 the four district hospitals were re-contacted to learn how the telemedicine service with the Royal Brompton Hospital was being used. Discussions were also held with the Brompton specialists. The service was now embedded in routine practice.

Pregnant women. DGH3 was still the only hospital to use the fetal cardiac service. Pre-recorded videos of ultrasound scans were transmitted once a month.

Newborns and other young babies. Three hospitals relied on the service for emergency advice, although these occasions occurred infrequently. The hospital with a Level 3 neonatal unit used the service very infrequently. Those babies with patent ductus arteriosus (requiring ligation) were increasingly being referred to another centre in London, because of reconfiguration of the service for premature PDA ligation in line with the wider reorganisation of neonatal networks.

Older children. The three hospitals hosting three- or four-monthly outreach clinics had continued with the telemedicine service. DGH2 and DGH4 normally held monthly teleconferences with the patients and parents present, while the teleconferences for DGH1 were held less frequently and videos of echocardiograms were transmitted. DGH3 was exploring the use of the service for this group of patients.

Telemedicine caseloads

The research project had focused on newly referred patients. Now, the telemedicine patients included new referrals and patients on review, including children who had undergone treatment in the Brompton two or three weeks previously. Teleconferences in which patients were scanned normally lasted 1¼ hours with 5, or perhaps 6 patients being presented. (The specialists found 1¼ hours to be the maximum length of time that they could concentrate when viewing transmitted images in the telemedicine suite.) An emergency case took 15 - 20 minutes. The sessions in which pre-recorded echocardiograms were transmitted lasted up to an hour and 8 patients were likely to be discussed.

The casemix of pregnant women whose anomaly scans were videoed for transmission included, as before, those at risk of a fetal cardiac anomaly (as identified by the obstetric department's protocol), and those of normal risk in whom a soft marker had been observed in the fetal heart. Fetal images from women with a high body mass index were also transmitted. A teleconferencing session typically lasted 40 - 45 minutes with 9 cases viewed. The operation of the fetal telemedicine service had been facilitated by two events: the obstetric ultrasound unit had a new ultrasound machine with inbuilt videoing functions, and the telemedicine equipment trolley was now stored in the unit for ease of use.

Operational issues

The telemedicine equipment provided by the project in 2001 was still in use and had proved to be reliable. During the project the hospitals met the costs of the ISDN-6 line rental and telephone link ups and, as the project ended, the business managers in the directorates were concerned about future charges against their hard-pressed budgets. However, the service had continued without the directorates becoming directly responsible for the quarterly invoices. The telemedicine equipment was being shared with cancer care networks in DGH1, the equipment having originally been installed in a central teleconferencing suite. Four or five teleconferencing sessions were booked weekly for use by the networks.

During the project a telemedicine co-ordinator in the Royal Brompton acted as the point of contact for the district clinicians when arranging a teleconferencing session. Sometime later, the post occupied by co-ordinator was withdrawn by the hospital trust, and instead, the district clinicians (or their secretaries) liaised directly with the specialists' secretaries. The specialists meanwhile had allocated slots in their monthly schedules for teleconferences. Occasionally, communication between these parties had failed to confirm whether or not a teleconference was going to take place. The project was dependent upon the Brompton co-ordinator also for dealing with technical difficulties. But as the months passed, the district clinicians became increasing confident about using the service, particularly in establishing ISDN contact with the Brompton telemedicine suite. Technical backup would still be needed at times, and the expertise might be provided within an IT department, for example.

Perceived benefits

For the specialists, the telemedicine service allowed them to keep their outreach workloads in check, especially as they were unable to increase the scheduled frequency of the clinics to cope with increasing demands. They perceived the district units as satellites to the Brompton, and they planned to extend the service to other hospitals in which they held outreach clinics. For the district clinicians, the service was valued for the immediacy of specialist access, the reassurance that patients and parents received, and for its educational benefits. These comments are from different hospitals.

> "I cannot emphasise enough how useful the line is for emergency/urgent cases – this avoids unnecessary transfer, or [an] urgent OPD slot being taken up by an infant who could wait to be seen."
>
> "It's an immense learning opportunity when you're showing patients and doing echos over the wires. It's really very, very good for us and of course it's good for our department because…it's quite a prestigious thing for us to be doing."

APPENDIX A

EXECUTIVE SUMMARIES FROM THE FIRST, SECOND AND THIRD REPORTS

APPENDIX A: EXECUTIVE SUMMARIES[#]

A) THE FIRST TELEPAED REPORT ON PAEDIATRIC CARDIOLOGY SERVICES

Context, objectives and research setting

1. Although the annual incidence of congenital heart disease in the United Kingdom appears constant, marked improvements in recent years in the mortality rates for treated cases have resulted in a sustained expansion in cohorts of children requiring monitoring by paediatric cardiology specialists. Their workloads also include monitoring infants with simple heart conditions that are likely to correct over time and screening newborns, infants and children with asymptomatic murmurs to exclude heart disease, the patients having been referred by consultant paediatricians in district hospitals.

2. In England, in 2002, there were 12 paediatric cardiology units staffed, on average, by five or six consultant specialists. Almost all units ran a system of peripheral outreach clinics held in networks of district hospitals on a monthly, bi-monthly or quarterly basis. Recently, a Paediatric and Congenital Cardiac Services Review Group, set up by the Department of Health, recommended that as much diagnosis and care as possible be provided in locally accessible outreach services [DoH, 2002a]. As the growth in consultant manpower in the specialty is only gradual, other methods for delivering services locally are needed, telemedicine being an option.

3. Telemedicine is considered as being integral for future models of care in the NHS [DoH, 2003c]. Although the technology is no longer new to healthcare, robust research evidence on the efficacy or cost effectiveness of differing types of applications is limited in its availability, although the situation is improving [Hailey et al, 2003]. Paediatric cardiology lends itself to telemedicine. The diagnosis of most presentations of congenital heart disease can be established from heart sounds using a stethoscope and ultrasound images and Doppler sounds transmitted by an echocardiogram machine. The outputs from both modalities are suitable for electronic transmission.

4. The TelePaed project was an economic evaluation of the role of telemedicine in providing specialist advice on fetal and paediatric cardiac care to consultants in district hospitals. The project aimed to identify and value direct NHS costs and direct non-medical costs associated with the introduction of telemedicine, to assess the health-related quality of

[#] The references cited in the executive summaries are listed at the end of this Appendix.

life of patients experiencing the alternative referral modes, and to synthesise the data on costs, morbidity and quality of life to establish the cost effectiveness of the technology.

5. Five hospitals participated in the project: a London specialist hospital and four district hospitals in which the London specialists held outreach clinics. Outreach clinics were held in three hospitals on a three- or four-monthly basis, and on a monthly basis in one hospital [DGH4]. The district hospitals were supplied with video conferencing packages incorporating a video recorder, document imager and electronic stethoscope sender, operated across ISDN-6 lines. Two hospitals were randomised to introduce telemedicine services from August 2001 and, six-months later, the other two hospitals introduced their services. The consultants in the hospitals determined how the telemedicine services linking their hospital with the specialist centre would be organised. This report, the first of four, focuses on the use of the technology for infants and children who would normally be referred to specialist outreach clinics held in district hospitals or, in exceptional circumstances, referred directly to a specialist centre.

Methods

6. Project facilitators in the district hospitals carried out prospective audits of all new patients seen by the specialists in the outreach clinics or via teleconsultations or as direct referrals to specialist hospitals. The audits identified hospital attendances and clinical tests and investigations undergone by the patients over periods of three to 12 months. The quality of life experienced by children shortly after their first specialist consultation and three months later was assessed from postal questionnaires completed by their mothers. The survey covered the months when the telemedicine services were operating. The health status of the children was assessed using the QUALIN instrument for children under 2 years [Manificat et al, 2000] and the PedsQL™ instrument for older children [Varni et al, 2001]. The initial questionnaire also asked about the costs incurred by the family when attending hospital and the mother's views of the clinic consultation or teleconsultation with the specialist. Finally, the district paediatricians and the specialists in London completed audit forms for the teleconsultations that they held.

7. Costs for 2001-02 were attributed to the resource use items recorded in the audits using information provided by the finance departments, pharmacy departments and business managers in the hospitals. As it was not possible to obtain all the required unit cost data from all district hospitals, weighted unit costs were used for attributing cost per resource item rather than mean costs. Durations of medical staff time spent on patient consultations were estimated from observational fieldwork and minutes of time were costed using NHS salary

scales. Annual equivalent costs for the packages of telemedicine equipment were estimated over an assumed lifetime of 5 years with a discount rate of 3.5%. The annual equivalent cost and the installation cost for each hospital were divided by the number of teleconsultations predicted for that hospital over a year to derive a technology cost per consultation.

8. Two techniques were used for analysing the patient datasets: a cohort analysis comparing the experiences of patients seen via teleconsultations and patients seen conventionally (non-telemedicine patients); and a 'matched cases' analysis, whereby the telemedicine patients were matched with non-telemedicine patients from the same hospital on a one patient to many, or many patients to one, basis. The matching technique was adopted because the cohorts of telemedicine and non-telemedicine patients differed in size and we wished to establish that the demographic and clinical attributes were similar. The cost analysis was undertaken from the perspective of the NHS and three levels of cost per new patient were generated: a first consultation, six-months of follow up, and total costs over six months. Non-NHS resources (i.e. family costs) were treated separately. As the patients' cost data were heavily skewed, non-parametric bootstrapping were performed, although the statistical tests were applied to the non-bootstrapped mean costs.

Results

9. Over the 15 months of fieldwork in four district hospitals, 214 new infants and children were assessed or screened for congenital heart abnormalities by paediatric cardiologists from the specialist centre and 4 were seen elsewhere in London. DGH4, with monthly outreach clinics, did not use the telemedicine service for outpatients. As a result, 47 new patients were discussed via telemedicine in three hospitals and 167 new patients were seen conventionally in four hospitals. The two groups of matched cases each contained 41 cases. The median age of the 214 patients was 4 years. The patients' presenting signs and symptoms were classified as normal, mild, moderate or severe: 71% (151/214) were classed as normal. There were no statistically significant differences in the demographic attributes and symptom severity for the two patient cohorts. The groups of matched cases had similar demographic attributes because the matching took account of age and symptom severity. DGH2 had higher proportions of patients with moderate or severe symptoms than the other hospitals ($p=0.027$).

10. Three clinical indicators were assessed for each patient: the management strategy arising from the diagnosis reached by the specialist; the outcome of the first contact with the specialist; and the status of the patient at the end of the project (whether discharged or continuing on review). 77% (164/214) were assessed for heart defects (usually presenting as

murmurs) and of these 45% (74/164) were found to have normal hearts and were discharged at the first attendance, while 5% (8/164) were serious and needed immediate admission. The remaining 23% (50/214) were assessed for arrhythmias and syndromes (e.g. Marfan's). There were no statistically significant differences in the three indicators for the telemedicine and non-telemedicine cohorts, and the groups of matched cases.

11. Questionnaires sent to 58 patients aged four months and older were used for calculating the health-related quality of life scores, 12 applying to patients who underwent teleconsultations. The analyses of the QUALIN scores and PedsQL™ domains on physical functioning, emotional functioning and social functioning indicated that both children under two years and older children who were seen via telemedicine had a slightly better, but not significantly better, quality of life than those with no telemedicine experience.

12. Having established from the clinical outcome data and the quality of life results that there was no statistically observable difference between the two patient cohorts, a cost minimisation approach was adopted for the cost analysis. Telemedicine first consultations were significantly more costly than non-telemedicine first consultations, most of which took place in outreach clinics, with the cost difference being attributable to the technology. The mean (SD) values were £357 (£123) vs £220 (£439) ($p=0.036$) for the patient cohorts and £338 (£13) vs £206 (£218) ($p<0.001$) for the groups of matched cases. However, after follow-up costs over six months were taken into account, telemedicine became the cheaper option, though not significantly so, the mean (SD) values for total six-months costs being: £861 (£2,523) vs £1,093 (£3,179) ($p=0.650$) for the patient cohorts and £555 (£1,140) vs £1,322 (£4,162) ($p=0.271$) for the matched cases.

13. Since both the teleconsultations and the outreach clinics were held in the district hospitals, no significant differences were observed between the patient cohorts in the lengths of the return journeys to hospital (median of 10 miles overall) and in the total costs (travel, loss of pay and incidental expenses) associated with the hospital visits (median of £7 overall). The median time spent in hospital was an hour and a half for both cohorts.

14. One-way sensitivity analyses explored four scenarios pertinent to the comparative patient costs. Conducting all telemedicine consultations by transmitting pre-recorded videos of echocardiograms without the patient being present reduced the mean cost per patient to £352, a difference from the baseline cost of only £5. Likewise, adding family costs to the first consultation costs had no impact on the results. Extending the maximum follow-up period to 18 months, with costs being discounted by 3.5% in the second year, made little difference -

non-telemedicine total costs continued to exceed the telemedicine total costs. However, when the telemedicine service costs (equipment and installation, training and rental packages) were shared across all patients (fetal, neonatal and paediatric) in the hospitals with suspected heart anomalies who were likely to undergo a teleconsultation, the mean cost of a first consultation for the telemedicine cohort was reduced by £27 to £330 and, consequently, first consultation costs were no longer significantly in favour of non-telemedicine patients (p=0.088).

15. Inter-hospital cost analyses were performed on the total patient cohorts (i.e. telemedicine and non-telemedicine patients combined). DGH2 with the higher proportions of moderate and severe symptoms also had the highest mean six-month total cost per patient (£1,670 (SD £4,331)) although significance was not reached (p=0.610). Among the 214 patients there were 5 who each incurred between £15,000 and £27,000 over six months. The impact of these outliers on the hospitals' six-months mean costs was assessed in a sensitivity analysis – see the table below. The adjusted cost distributions for the four hospitals were remarkably similar, yet they had different configurations of services.

Table A1 District hospital total six-month bootstrapped costs per patient excluding 5 outliers over £15,000

Main analysis				
	DGH1	DGH2	DGH3	DGH4
Number Mean (SD) 95% confidence limits	68 £1,027 (£3,356) £525 to £2,517	33 £1,670 (£4,331) £651 to £4,014	59 £802 (£2,373) £407 to £1,916	54 £942 (£2,374) £520 to £2,041
Sensitivity analysis excluding 5 outliers over £15,000				
	DGH1 excluding 1 outlier	DGH2 excluding 2 outliers	DGH3 excluding 1 outlier	DGH4 excluding 1 outlier
Number of patients Mean (SD) 95% confidence limits	67 £651 (£1,449) £396 to £1,174	31 £692 (£1,094) £314 to £2,125	58 £547 (£1,295) £310 to £1,090	53 £672 (£1,325) £424 to £1,289

16. In the satisfaction survey, parents involved in teleconsultations and parents involved in outreach consultations rated 11 identical statements about the process. The parents' views were consistently much more positive than negative for both consultation modes. Few were embarrassed speaking to the specialist (12% for clinic consultations and 5% for teleconsultations). However, parents who underwent teleconsultations felt they were better briefed beforehand about the consultation process (p=0.022); they could also see more clearly the pictures which were being considered (p=0.003). The district paediatricians' audit assessments of 83 teleconsultations with infants and children showed that the image and

sound qualities were acceptable for over 90% of consultations. After half the teleconsultations the doctors revised their plans in some respect for managing the patients. Two patients were transferred to London.

Discussion

17. The four district hospitals were 35 to 65 miles from central London and they were among nearly 40 hospitals in which paediatric cardiologist staff from the specialist hospital held outreach clinics. The case mixes of the patient cohorts were predominantly suspected heart murmurs that were frequently found to be normal. This was also the prevailing outcome in a series of echocardiograms transmitted from a remote hospital to a specialist centre in Switzerland – 40% of patients had normal hearts [Widmer et al, 2003]. The TelePaed patient cohorts did not appear, therefore, to be atypical.

18. An economic evaluation of virtual outreach services between two NHS hospitals and 29 general practices was a useful comparator for the TelePaed evaluation [Jacklin et al, 2003], since both studies calculated patient costs for first consultations (teleconsultations vs clinic outpatients) and after six-months follow up. The equivalent annual costs of the videoconferencing systems were the key cost components in both studies. The annual number of virtual consultations was 500 and Jacklin found that this annual rate passed the threshold where important economies of scale relating to the technology remained available; with TelePaed, the sensitivity analysis exploring shared use of the telemedicine systems suggested that there was still scope for achieving economies of scale. The virtual outreach trial found that a significantly greater proportion of patients in the virtual consultation groups were offered a follow-up hospital appointment (51% vs. 41%, $p<0.0001$). In contrast, in TelePaed, there was almost no difference in the follow-up rates for the two patient cohorts (57% and 55%), a finding attributable to the high specification of the equipment packages for transmitting images and the ultrasound training received by the district paediatricians.

19. Even though there was almost no difference in the district hospitals' mean six-month patient costs when adjusted for outliers, the three hospitals that introduced telemedicine services for this purpose could have had substantially higher operating costs because the new services complemented their existing outreach services, rather than substituting them. However, from the perspective of the parents, telemedicine had two commanding attributes: waiting times for obtaining appointments for a specialist opinion could be reduced, while, for more urgent cases, exhausting and costly journeys to London could be minimised.

20. The telemedicine equipment was also used in the hospitals by the neonatal services and, in one hospital, by the obstetric fetal medicine service. The other applications are being reported separately. The final report from the project will review the economics of these integrated services and it will also address wider issues about configuring and contracting telemedicine services between secondary and tertiary sectors in the NHS.

B) THE SECOND TELEPAED REPORT ON FETAL CARDIOLOGY SERVICES

Context, objectives and research setting

1. Although the annual incidence of congenital heart disease in the United Kingdom appears to be constant at 6.0 per 1000 live births and marked improvements have been achieved over past decades in survival rates following treatment, prenatal detection rates remain a cause for concern. In England and Wales, between 1993 and 1995, 25% of new cases of complex cardiac abnormalities were diagnosed prenatally. As half were terminated, the prenatal detection rate for live births with complex abnormalities was 13% [Bull, 1999]. There is evidence that by providing fetal ultrasound training programmes in district hospitals, detection rates may reach 36% [Hunter et al, 2000]. Moreover, a specialist fetal medicine centre in London has reported a rate of 75% for major cardiac defects in the local resident population [Carvalho et al, 2002].

2. Fetal anomaly scans are carried out in hospital obstetric units at 18 to 22 weeks gestation, the timing depending upon local policies. Obstetric sonographers usually perform the ultrasound scanning to check for possible malformations in anatomical structures. Minimum standards have been identified and they include the thorax at the level of a four-chamber cardiac view. Visualising cardiac outflow tracts is an optimal standard, because additional scanning time is needed [RCOG, 2000]. The advantages of prenatal diagnosis are two fold: parents can be counselled on whether or not to continue the pregnancy, and when a pregnancy continues, the management of the mother's obstetric care and the newborn baby can be planned. Research evidence shows that mortality rates are reduced and morbidity levels are improved following prenatal diagnostic disclosure.

3. If a routine anomaly scan reveals a fetal heart abnormality, the mother will probably be referred to a specialist (a perinatal cardiologist) for assessment. Referrals may also be made in other circumstances: where there is a suspicion that an anomaly exists; and when confirmation is needed that the heart is normal, possibly because the ultrasound images during the anomaly scan could not be visualised satisfactorily or, more likely, the parents have an elevated risk for congenital heart disease.

4. Perinatal cardiologists in England are based in 12 tertiary paediatric cardiology units, although they may hold sessions in a nearby fetal medicine centre that provides a regional service. As there are so few centres, many referred women are making lengthy and time consuming journeys. For all women, there are travel and incidental costs, such as child minding, and a possible loss of earnings for themselves or their partner.

5. The TelePaed project is an economic evaluation of the role of telemedicine in providing specialist advice on fetal and paediatric cardiac care to clinicians in district hospitals. This report, the second of four, is on the use of the technology in fetal medicine. [#] Telemedicine is considered as being integral for future models of care in the NHS [DoH, 2003c]. Although the technology is no longer new to healthcare, robust research evidence on the cost effectiveness of differing types of applications is limited in its availability, although the situation is improving [Hailey et al, 2003]. As a technology, fetal ultrasound is a suitable candidate for telemedicine. The digital images from obstetric ultrasound machines are easily transmitted electronically, either via a 'live' link up or via the transmission of pre-recorded videotaped ultrasound examinations.

6. Four district hospitals in south-east England participated in the project, each having between 3000 and 4000 maternal deliveries annually. Telemedicine equipment was installed in the hospitals to enable a telemedicine service to be established with perinatal cardiologists in a specialist centre in London. The obstetric consultants and sonographers in each hospital were not obliged to take up the service, and only one hospital, DGH4, made use of it.[*]

Methods

7. Over 15 months of fieldwork, project facilitators in the district hospitals carried out prospective audits on pregnant women undergoing anomaly scans who met the project's criteria for above average risk for fetal congenital heart disease (cardiac risk women) or the hospitals' criteria for estimating above average risk for Down's syndrome (assessed risk women). Other women who were referred to specialists (low risk women) were also identified, as well as samples of normal (baseline) women. The audits identified hospital antenatal scans and check-ups and outpatient clinic attendances from the time of the anomaly scan onwards, prenatal admissions, mode of delivery, and time spent on the labour ward and postnatal ward. Attendances with specialists in London were recorded and also events involving the use of the telemedicine equipment in DGH4.

8. Costs for 2001-02 were attributed to the resource use items recorded in the audits using information provided by finance officers and business managers in the district hospitals and two fetal medicine centres. As it was not possible to obtain all the required unit cost data from all district hospitals, weighted unit costs were used for attributing cost per resource use

[#] The first report was on paediatric cardiology outpatient services; the third report will be on neonatal cardiology services; and the final report will provide an overview.

[*] The identity codes for the four hospitals were re-allocated randomly between the First and Second Reports.

item rather than mean costs. Medical staff time, calculated in minutes, was costed using NHS salary scales and the manual by Netten and Curtis [2002]. Annual equivalent costs for the telemedicine equipment packages were estimated over an assumed lifetime of 5 years with a discount rate of 3.5%. The annual equivalent cost and installation cost for DGH4 were divided by the total teleconsultations over a year to derive a technology cost per consultation

9. The quality of life experienced by women a few weeks after their anomaly scan and three months later was assessed from postal questionnaires sent to patients attending DGH2 and DGH4, since these hospitals regularly referred patients to the perinatal cardiologists based in the specialist telemedicine centre. HADS was used to assess levels of anxiety and depression, while the EuroQol EQ-5D instrument assessed the women's health. Family costs incurred when attending hospital for antenatal visits were recorded in the questionnaires. The response rates were 64% for the initial survey and 76% for the follow-up survey.

10. Modelling was used to predict the likely levels of telemedicine usage in the other three hospitals assuming they had also taken up the telemedicine service. First, a logistic regression model was fitted to all referred women at DGH4, and risk status and gestation week of the anomaly scan were found to be significant predictors of whether or not patients were assessed via telemedicine. The logistic regression model was then applied to all women referred for fetal echocardiography in the other hospitals in order to predict the women who would have been telemedicine cases. Model uncertainty was adjusted for in a sensitivity analysis.

11. The cost analysis was undertaken from the perspective of the NHS and three levels of cost per patient were generated: antenatal cost from the time of the anomaly scan; maternal delivery cost; and total obstetric cost incorporating both the antenatal and delivery costs. Non-NHS resources (i.e. women's costs) were treated separately. As the patients' cost data were heavily skewed, non-parametric bootstrapping were performed, although the statistical tests were applied to the non–bootstrapped mean costs.

Results

12. Altogether, 1151 women in the three risk groups (i.e. eligible women) were identified: 231 in DGH1, 310 in DGH2, 275 in DGH3, and 335 in DGH4. Among the 1151 women, 48% had a cardiac risk factor, 37% an assessed risk factor, and 15% were low risk. Assessed risk women in every hospital were significantly older than cardiac risk women. Almost half the cardiac risk women were expecting twins. The hospitals had different conventions over the gestational age when women should have a fetal anomaly scan, these conventions being

determined by the wider policies in the local antenatal screening programmes over the selection of serum screening tests and age-adjusted risk cut-off level, and the role of nuchal translucency screening in the first trimester. Consequently, gestational ages when women entered the TelePaed audit ranged from 17 weeks in DGH2, a hospital that did not offer nuchal scans, to 23 weeks in DGH3 where all women were offered a nuchal scan.

13. Incidence rates per 1000 maternal deliveries for provisional or confirmed fetal cardiac abnormalities were similar in three of the four hospitals, ranging between 2.9 and 4.0; the rate for the fourth hospital was lower at 0.7. A specialist member of the TelePaed project team assessed the severity of the 50 cases of suspected abnormalities: 37 had severe or moderately severe diagnoses; 3 were mildly severe; and 10 were normal. Incidence rates based on the 37 moderate or severe diagnoses were calculated. The rates were 23.6 per 1000 assessed risk pregnancies; 20.8 per 1000 cardiac risk singleton pregnancies; 7.5 per 1000 multiple pregnancies; and, overall, 2.1 per 1000 maternal deliveries.

14. Patients were referred to specialists for three reasons: to confirm or exclude a suspected fetal heart anomaly; to screen the fetal heart (and possibly other organs); or to confirm or exclude a non-cardiac diagnosis. Almost all cases reaching the anomaly scan stage and diagnosed in the district hospitals as having a cardiac abnormality were referred to specialists. (The other cases were terminated immediately.) Three hospitals each referred 10 to 17 cardiac cases and one referred 3 cases. However, diverging practices were observed over tertiary fetal heart screening. Converted into screening referral rates per 1000 maternal deliveries, the rates for two hospitals were similar – 12.6 per 1000 for DGH3 and 11.1 per 1000 for DGH4, unlike the rate for DGH1 which was double in size (25.8 per 1000), while DGH2, having referred only one patient for this purpose, had a rate of 0.3 per 1000. This diversity in the referral patterns meant that when the modelling was undertaken to predict the use of a telemedicine service, a spectrum of plausible scenarios was considered.

15. In the first postal survey, cardiac risk women had noticeably higher levels of anxiety and depression than assessed risk women. They also perceived their health to be poorer than assessed risk women. (There was no observable difference between cardiac risk women expecting twins and those with singleton pregnancies.) Three months later the anxiety levels of cardiac risk women had eased significantly, both in women who completed their questionnaire before delivery and those who completed it after delivery. Total costs (travel, loss of pay and incidental expenses) were similar for 232 women attending the two district hospitals, the overall mean cost being £7. For 9 women who attended London

hospitals, the mean total cost was £56 and they spent at least 3 hours longer on the visits, inclusive of travel time, than patients attending local hospitals.

16. The telemedicine service in DGH4 was used by the clinicians in the Obstetrics department in two ways: for screening women who met the department's protocol for identifying cardiac risk, and for establishing the severity of a diagnosed abnormality. Teleconsultations, organised in monthly sessions, were held for 52 women over 12 months, and the purpose of 90% of the teleconsultations was to screen high risk women. When considering personal cost implications, telemedicine women had no additional expenditure because the ultrasound images of the fetal heart were recorded on videotape during their routine anomaly scan. These women and the women seen face-to-face by specialists had similar levels of anxiety, depression, and perceptions of wellbeing. However, both groups were significantly more anxious than women who were not referred ($p=0.001$).

17. When preparing the cost datasets, different patterns emerged in the hospitals' delivery of antenatal care, so it was inadvisable to make inter-hospital comparisons over antenatal costs. For example, eligible women in DGH4 averaged 11 visits to hospital antenatal and outpatient clinics, while in DGH2, the average was 3 visits with the rest of the care provided in the community. Thus the mean antenatal costs for eligible women in the two hospitals were £624 and £291 respectively. The mean antenatal costs for women who formed the baseline normal cohorts in these hospitals were similarly disparate at £455 and £145 respectively. The cost analyses also showed that the mean costs for cardiac risk women constantly, and significantly, exceeded the mean costs for assessed risk women.

18. The resource costs for the telemedicine service in DGH4 showed a marginal extra cost to the NHS of a teleconsultation over a specialist consultation in London of about £100. However, by the time other events in the women's antenatal care were accounted for, the difference in the mean antenatal costs for the referral modes was only £60 (£824 v £764), and for the total package of obstetric care, including delivery costs, £126 (£3,186 v £3,060).

19. Logistic regression modelling used to predict what proportion of the referred women from the other three hospitals might have been telemedicine cases, was based on the observed experience in DGH4. First, reassurance about the model's predictive accuracy was obtained by fitting it to the observed patients: 74% were predicted as being assessed by telemedicine and this rate was similar to the actual percentage (68%) involved in teleconsultations. The predictions of referred women as telemedicine cases from the logistic regression modelling varied by centre: 66% for DGH1; 100% for DGH2; and 50% for DGH3.

There was a degree of uncertainty in these predictions since the four hospitals had different policies for screening pregnant women. So a Monte Carlo simulation technique was used to adjust for uncertainty in the model predictions. After adjustment, the mean percentages of women predicted as telemedicine cases were similar to the percentages predicted in the original model, although for DGH2, with the smallest sample size (and referral rate), the telemedicine prediction was now 82% instead of 100%.

Predicting the costs of telemedicine referrals

20. Using the results from the logistic regression modelling, cost analyses were performed comparing predicted use of the telemedicine versus direct referral mode for the three hospitals. Cost analyses were also performed on the predicted use for all four hospitals after adjustment from the sensitivity analysis. In the first table below, telemedicine women in DGH1 incur a lower mean antenatal cost than women referred directly because the expenditure on the telemedicine service would be shared among 84 users resulting in a cost per case for the technology being lower than the cost of specialist echocardiography. Telemedicine would have only a marginal impact on total obstetric costs in DGH1.

21. The sensitivity analysis for antenatal care based on model uncertainty in the second table suggests that the telemedicine service in DGH4 would be almost cost neutral if the volume of users was increased slightly from 52 (the actual number in 12 months) to 54 (the predicted number). The sensitivity analysis continued to favour the telemedicine option in DGH1, the high referring hospital, while the direct referral option was cheaper for the two low referring hospitals, DGH2 and DGH3.

Comparative magnitudes of the mean costs for referred women according to referral mode predicted from the logistic regression modelling and the sensitivity analysis

Care scenario	Mean costs for referred women according to predicted referral modes (n=Direct v Telemed)			Observed mean costs
	DGH1 (n=43 v 84)	DGH2 (n=0 v 11)	DGH3 (n=17 v 17)	DGH4 (n=24 v 52)
Antenatal	Direct > Telemed	Telemed only	Direct < Telemed	Direct < Telemed
Total obstetric	Direct ≥ Telemed	Telemed only	Direct < Telemed	Direct ≤ Telemed

Care scenario	Mean costs for referred women according to referral modes predicted under model uncertainty (n=Direct v Telemed)			
	DGH1 (n=42 v 85)	DGH2 (n=2 v 9)	DGH3 (n=16 v 18)	DGH4 (n=22 v 54)
Antenatal	Direct > Telemed	Direct < Telemed	Direct < Telemed	Direct ≤ Telemed
Total obstetric	Direct ≥ Telemed	Direct > Telemed	Direct < Telemed	Direct ≤ Telemed

Symbols: > indicates the mean cost for direct referral was greater than the mean cost for telemedicine; < indicates the mean cost for direct referral was lower than the mean cost for telemedicine; for total obstetric care, ≥ and ≤ indicate comparative mean costs for the two referral modes that were within £100, while for antenatal care, ≤ indicates a mean cost difference of £11.

Discussion

22. Although the ‘hub and spoke’ model of perinatal cardiologists working in large fetal medicine/obstetric centres linked to a paediatric cardiology unit may represent best practice, as it permits comprehensive assessment of affected fetuses by a variety of fetal specialists working together [Gardiner, 2001], the model will not moderate the workloads of the cardiologists unless a change of practice is adopted enabling them to reduce the amount of time spent on the majority of patients whose fetuses are normal. This project provides an indication of the potential workloads for perinatal cardiologists. The overall fetal cardiac referral rate from four district hospitals was 15.5 per 1000 maternal deliveries. Applying this rate to England, where 548 033 deliveries were registered in 2002-3 [ONS, 2004], results in 8500 being referred annually to perinatal cardiologists, or an average caseload of 700 for each of the 12 paediatric cardiac units in England. Although there is no benchmark against which to assess this projection, it is worth noting that paediatric cardiologists in the fetal medicine centre in Birmingham, which provides tertiary services for the West Midlands region, scanned 503 women in 2000/1, of whom 80% were normal [Kilby and Higgs, 2001].

23. The demand for specialist fetal echocardiography in the NHS over the next few years is likely to accelerate. The UK National Screening Committee has an ongoing review of antenatal ultrasound screening with recommendations due to be issued in 2004 [UK National Screening Committee, 2004]. Raising standards of anomaly screening in district maternity services should lead to higher detection rates of unequivocal and equivocal cardiac diagnoses. Fetal cardiac risk factors may become more prevalent among women of childbearing age, thereby increasing screening workloads, as more and more survivors of congenital heart disease (both males as potential fathers and females) reach adulthood, and if the current upward trend among females for developing type 2 diabetes remains unchecked. [Feig and Palda, 2002]. Maternal obesity can impede visualisation of the fetal heart, and the obesity rates in the general population are now a public health concern.

24. Variations in obstetric policies in the four district hospitals impacted on the evaluation in three ways. Different practices in the districts’ screening programmes for Down’s syndrome affected the numbers of women entered in the TelePaed database. The hospitals’ obstetric departments had differing conventions for obtaining specialist fetal assessments and these conventions determined the numbers of referrals over the 15-month fieldwork period. Finally, the obstetric departments had well established tertiary links with different fetal medicine centres in London, and this factor influenced the take up of the telemedicine service. Nevertheless, by undertaking thorough analyses of the clinical, resource cost, and survey datasets combined with statistical modelling, general conclusions can be drawn.

Relations between referral rates and antenatal mean cost per patient for referral modes predicted under model uncertainty

Fetal cardiac referral rate ranking	District hospital	Fetal cardiac referral rate per 1000 deliveries (referrals/deliveries)	Antenatal mean costs by referral mode predicted under model uncertainty
High	DGH1	29.8 (127/4260)	Direct **>** Telemedicine (£465 vs £438)
Medium	DGH4	11.1 (76/5118)	Direct **≤** Telemedicine (£795 vs £806)
Low	DGH3	7.5 (34/4517)	Direct < Telemedicine (£479 vs £790)
Very low	DGH2	2.9 (11/3828)	Direct < Telemedicine (£649 vs £1,156)

Symbols: Refer to the previous table for an explanation for the symbols of **>,** <, and **≤** for antenatal care.
Note: The referral numbers are those used logistic regression modelling and the cost analyses were based on the modelling.

25. From the perspective of the NHS there was a strong relationship between the hospitals' volumes of fetal cardiac referrals (expressed as referral rates in the above table) and their mean antenatal costs per patient for the predicted referral options: the bigger the referral rate, the greater the likelihood that the marginal antenatal cost would favour telemedicine. Mean antenatal patient costs were not, by themselves, a guide on whether or not one referral option 'dominated' the other. To illustrate, the mean antenatal costs per patient for DGH1 and DGH4, where telemedicine was either the dominant or equivocal option, differed by more than £300, mainly because women in DGH4 had many more hospital attendances.

26. We must also consider the appeal of telemedicine for referred women who are invariably in the second trimester of their pregnancy and are generally more anxious than women who are not referred, and of whom two thirds will have other children. Women who were assessed via telemedicine were spared a second visit to hospital because the fetal heart video was recorded while they were undergoing their anomaly scan. Those who were referred directly to London experienced a visit taking around 5 hours and an expenditure of over £50. In terms of women's opportunity costs, the case in support of the telemedicine option seems persuasive. However, in the context of the Government's current health strategy offering patient choice, research is needed to assess women's preferences over referral modes, taking account of clinical circumstances surrounding the referral decisions.

27. The telemedicine equipment was also used in all four hospitals by the neonatal services and, in three hospitals, by the paediatric cardiology outpatient services. The final report from the project will review the economics of these integrated services and address wider issues on configuring and contracting telemedicine services between secondary and tertiary sectors in the NHS.

C) THE THIRD TELEPAED REPORT ON NEONATAL CARDIOLOGY SERVICES

Context, objectives and research setting

1. Around 60% of all cases of congenital heart disease in England are diagnosed in babies under one year, and for a third these cases, the disease is detected within the first 6 weeks of life [Wren at al, 1999]. As early recognition of congenital heart disease in the neonate is important because deterioration may be sudden and some treatable defects may cause death if diagnosis is delayed, it is usual for district paediatricians (neonatologists) to rapidly transfer babies with severe symptoms to a paediatric cardiology centre.

2. Neonates with moderately severe clinical problems may also be referred to cardiac centres although not as a high priority. Reasons for referral can include requests for diagnostic clarification or advice on the immediate management or long-term management of the baby. For some cases the district paediatricians may adopt a 'watch and wait' approach before seeking specialist advice, especially for extremely premature babies. Non-critical cases may attend as day cases, often for echocardiography or a procedure.

3. There are 12 paediatric cardiology centres in England staffed by 66 consultant specialists and the centres have a limited capacity for providing neonatal intensive care. There are occasions when a centre does not have a suitable neonatal cot available and cannot accept a transferred baby and another receiving centre then has to be found with further delays in treatment. Traditionally, a transfer has involved a retrieval team from the centre travelling by ambulance to the source hospital to collect the baby, with the total journey time taking 4 hours or more in many instances [Kempley and Sinha, 2004].

4. Most congenital heart disease in neonates can be diagnosed from ultrasound images and Doppler sounds transmitted by an echocardiogram machine, and the outputs from this modality are suitable for electronic transmission via telemedicine. A rapid literature search found accounts of seven telemedicine services world wide for neonatal congenital heart disease and eight services for both newborn babies and older infants and children. Where costs were presented, they applied to the teleconsultation or transportation events, so it was impossible to assess the impact of telemedicine on the patients' overall costs of care.

5. The TelePaed project is an economic evaluation of the role of telemedicine in fetal, neonatal and paediatric cardiac care. This, the third report, is on the use of the technology in neonatal medicine. The first was on paediatric cardiology outpatient services, the second on fetal cardiology services, and the final report will provide an overview across all services.

6. Four district hospitals in south-east England participated in the project. Although the hospitals' maternity units had between 3,000 and 4,000 deliveries annually, their neonatal services were different in scope. DGH2 was a regional centre for neonatal intensive care and provided Level 3 care, as defined by the British Association of Perinatal Medicine [BAPM, 2001]. DGH4 was an accredited sub-regional referral unit providing Level 2 care (i.e. short-term intensive care); the neonatal unit in DGH1 also provided Level 2 care. Finally, in DGH1, Level 2 care was provided, although the funding was for a Level 1 unit.*

7. The hospitals with the regional or sub-regional neonatal units had regular access to the telemedicine service over 12 months, since they had been randomised as intervention sites. The access period for the two control hospitals was 6 months. The neonatologists were not obliged to use the service and DGH3 never used it for neonatal referrals. Telemedicine referrals were made to one of the three paediatric cardiology centres in London while direct referrals involving transportation were sent to all three centres.

Methods

8. Over 15 months, project facilitators in the district hospitals carried out prospective audits on all 'at risk' babies, the eligibility criteria covering: premature babies under 32 weeks gestation or under 1800 grams at birth; older or heavier babies with heart symptoms; and other newborn babies undergoing an echocardiogram (e.g. babies with Down's syndrome). 491 babies met the eligibility criteria, of whom 77% (378/491) weighed less than 1800 grams.

9. Information was captured on babies' admissions to the district neonatal units according to the level of intensity of care and to the specialist hospitals. Follow-up outpatient attendances and ward visits were recorded, as well as echocardiograms, catheterisations and surgical procedures; likewise teleconsultations and transportations to, and from, London.

10. Costs for 2001-02 were attributed to the resource use items, the hospital costings having been provided by finance officers and business managers in the district hospitals and the telemedicine centre. As it was not possible to obtain all the required unit cost data from all district hospitals, weighted unit costs were used for attributing cost per resource use item. NHS salary scales and the manual by Netten and Curtis [2002] were used to cost medical staff time calculated in minutes. The telemedicine components covered the equipment and ISDN-6 line installation, training, line rental and call charges, and the time spent by the clinicians involved in each consultation. Annual equivalent costs for the equipment were

* The identity codes for the four hospitals were re-allocated randomly between each report.

estimated over an assumed lifetime of 5 years with a discount rate of 3.5%. The ambulance transfer cost covered costs borne by an ambulance service (vehicle and crew, return journey mileage, and waiting time at the district or specialist hospital) and costs borne by a retrieving hospital - travelling incubator, disposable items, drugs, and neonatal staff time.

11. The cost analysis was undertaken from the perspective of the NHS and two levels of cost per referred baby were generated: an initial 14 days of neonatal care, and a maximum period of 6 months. The commencement date of these periods was the day of birth or the day of re-admission to hospital or, for premature babies for whom a decision to seek specialist advice was delayed for some days or weeks, the day when the referral decision was reached. Non-parametric bootstrapping were performed to obtain mean costs per baby.

12. The baseline cost analysis assumed that the neonatal telemedicine services were ‘stand alone' services and were not shared with other users. For the sensitivity analysis, the cost of the telemedicine service in each hospital was shared among all babies and children who used the service. Logistic regression modelling was undertaken to gauge whether the results for the telemedicine usage could be generalised to neonatal services elsewhere.

Results

13. 40 of the 491 babies in the TelePaed database were referred to specialist paediatric cardiologists in London. 17 babies were from DGH2 and the other hospitals referred 7 or 8 babies each. 23 babies were transported directly to London and 17 babies were assessed via the telemedicine service. DGH2 held teleconsultations for 9 babies, DGH4 held teleconsultations for 6 babies, and DGH1 held teleconsultations for 2 babies. DGH3 did not use the neonatal telemedicine service.

14. There were no statistically significant differences between the directly referred babies and telemedicine babies in terms of gender, birthweight or days between birth and the specialist assessment. Three-quarters of all the referred babies weighed more than 1800 grams when born; 7 had actually been discharged home and re-admitted with heart symptoms. Two-thirds (27) of the babies had symptoms of suspected congenital heart disease and the symptoms for the other babies included abnormal heart rhythms, pulmonary hypertension of the newborn (PPHN), and problems associated with immature hearts.

15. When the symptoms for suspected congenital heart disease were re-classified into critical, and non-critical disease, 10 babies were in a critical condition. Only 2 of these babies were assessed via telemedicine; the technology was more likely to be used for babies with

immature heart problems or PPHN in mature babies. As a result, patterns in the delivery of care differed between the referral methods. 65% of directly referred babies were admitted to a specialist NICU during their first 14 days compared with only 18% of telemedicine babies, although the average length of stay for both groups of babies was 9 days.

16. In the 14-day baseline analysis covering the four hospitals, the mean cost for the direct referral group was £11,760 and it was £3,840 greater than the mean cost of £7,920 for the telemedicine group, but the cost difference was not statistically significant. Within every hospital using the telemedicine service the mean 14-day cost for the telemedicine babies was lower than the mean cost for directly referred babies. The 6-month maximum baseline cost analysis produced relatively similar mean costs for the referral methods (i.e. direct referral £22,810 and telemedicine £22,850). However, there were several very premature babies in the telemedicine cohort who incurred particularly high costs primarily because a cot day was the main cost driver, especially for an intensive care cot in a district hospital or a cot in a specialist NICU.

17. In the one-way sensitivity analysis, in which the cost for the telemedicine service in each hospital was shared among all babies and children who had a teleconsultation, there was a reduction of £460 in the 14-day mean cost per telemedicine neonate (from £7,920 at baseline to £7,460). The inter-group difference was still not statistically significant. However, DGH4, with the largest teleconsultation caseload of babies and children (40 in all), experienced a statistically significant reduction of nearly £1,000 in the 14-day neonatal telemedicine mean cost when the telemedicine service costs were shared among all users.

18. After first establishing that urgency (i.e. a critical condition) was a statistically significant characteristic of referral method when comparing telemedicine and directly transferred babies from DGH1, DGH2 and DGH4, a multivariate logistic regression model was fitted to the dataset for the 33 babies to obtain for each baby a prediction score for referral method selection. (The log-likelihood function indicated a well fitting model.) The overall predictive accuracy of the model was 76%; 12 of the 16 transferred babies were predicted to use this method, and 13 of the 17 telemedicine babies were predicted to be selected for telemedicine.

19. The district and specialist clinicians audited the neonatal teleconsultations, although the coverage was not fully comprehensive partly because of the unpredictable scheduling of these events. Normally each consultation took place on the same day as the referral decision was reached and a single baby was discussed during a telemedicine link up. The average

duration of the link ups was 20 minutes. An echocardiogram was always transmitted – either a pre-recorded video or a live examination. The transmitted visual images and sounds were satisfactory, but sometimes pixelation of an echocardiogram occurred although the problem never caused a consultation to be terminated. The district neonatologists were advised on two occasions to transfer a baby to London.

Discussion

20. A perceived advantage of telemedicine is that it can reduce parental anxiety and family expenditure when doctors are advised not to transfer a baby to a specialist centre. A survey of the mothers of the TelePaed neonates was piloted, but the methodology was too insensitive in the stressful circumstances. Undertaking case studies with parents may be a more satisfactory way to learn about the tradeoffs that they face when a baby is transferred – should they travel to the centre or wait until the baby is returned to the district hospital?

21. The uptake, and usage levels, of the neonatal telemedicine service in the hospitals were influenced by two inter-related factors: echocardiographic facilities and skills, and casemix. The regional and sub-regional neonatal units already had echocardiogram machines and once the neonatologists were confident about their examination skills for transmission purposes, they made regular use of the telemedicine service. When offered regular access to the telemedicine service neither the district neonatal unit nor the special care baby unit had a suitable echocardiogram machine, and only one unit purchased a machine before the project ended. These hospitals were also reliant on London obstetric units linked to paediatric cardiology centres for delivering babies diagnosed prenatally with congenital heart disease. It is apparent, therefore, that regional or sub-regional neonatal units would make the greatest use from stand-alone cardiac telemedicine services when first introduced. Cost savings associated with a neonatal cardiac telemedicine service would be greatly enhanced if the service could be used both for neonatal and paediatric referrals.

22. Extrapolating from the TelePaed datasets, the upper estimate for transferred newborn babies with heart problems in the UK is 2.2 per 1000 live births or 1530 babies per annum, giving an average annual caseload of 102 neonatal admissions for the 15 specialist paediatric cardiology centres. If telemedicine services were widely implemented in neonatal networks, the average annual caseload of transferred newborns might be lowered to 1.7 per 1000 births or 1182 babies. This would reduce the annual neonatal caseload per centre to 79 admissions (a reduction of 23%). Of course, transferred neonates form only part of the caseloads treated in the paediatric cardiology centres. Nevertheless, since the specialty of paediatric cardiology has relatively few consultants (66 in England in 2004 [DoH, 2004a]),

any opportunities for restricting the size of current caseloads in the specialist centres must deserve consideration.

23. In 2003, the Department of Health's review group on neonatal intensive care services recommended the setting up of managed clinical networks in which hospitals with differing types of neonatal units within geographical areas worked together [DoH, 2003c]. In early 2005 there were 24 networks in England either being set up or in operation and they usually incorporated 6 to 10 hospitals with special care (Level 1), high dependency (Level 2) and intensive care (Level 3) units. (The Department of Health made a financial commitment of £72 million over three years, 2003/4 to 2005/6, towards implementing the recommendations and the amount set aside for 2005/6 was £20m [DoH, 2003d].)

24. There appears to be an opportunity now for exploring the introduction of telemedicine links between neonatal networks and their regional paediatric cardiology units. Our logistic regression modelling found that the variable of 'urgency' was the strongest predictor of referral method selection. This modelling technique, if applied to the current caseloads of neonatal cardiac referrals from neonatal units within networks, could facilitate a telemedicine implementation programme by identifying those units likely to achieve greatest cost savings.

25. Paralleled with these network developments has been the setting up of neonatal transport services with dedicated retrieval teams. Prior to the introduction of the service in south-east England, delays of more than an hour frequently occurred before an ambulance reached the transferring team and then the team had to travel to the source hospital to collect the baby, with further time possibly being spent on stabilising the baby clinically before departing for the destination hospital [Kempley and Sinha, 2004]. Reductions in transfer times achieved by the dedicated transport services will undoubtedly benefit the welfare of all sick and distressed neonates, the majority of whom are born prematurely. Our research suggests that these services might be further enhanced by the introduction of telemedicine systems to facilitate remote triage in babies with immature heart problems. 10 of the 40 referred babies were severely premature (under 1600 grams) and by using the telemedicine service, 5 avoided ambulance transportations both to, and from, London.

26. The telemedicine equipment installed in the district hospitals for the TelePaed project was used also by the fetal medicine and paediatric services. The final report will review the economics of integrating these services, taking account of other uses made of the telemedicine equipment, and it will also address wider issues about configuring and contracting telemedicine services between secondary and tertiary sectors in the NHS.

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APPENDIX B

DESIGN OF THE TELEPAED PROJECT [FROM THE FIRST REPORT]

APPENDIX B: DESIGN OF THE TELEPAED PROJECT [FROM THE FIRST REPORT]

The project was designed to evaluate the role of telemedicine in facilitating diagnosis and advice on the management of:

- Suspected fetal heart defects identified during the routine 18-20 weeks screening of pregnant women;
- Newborn babies with suspected heart abnormalities;
- Babies, toddlers and children for whom an urgent cardiac opinion is required and other newly referred patients who would otherwise be seen by specialist in their routinely scheduled outreach clinics.

By installing telemedicine facilities in district hospitals for use by paediatricians and obstetricians a number of benefits were anticipated. Telemedicine could:

- Facilitate early and accurate diagnosis in newborn babies and enable appropriate transfer and management strategies to be determined with a potential reduction of mortality and morbidity [Franklin et al, 1991];
- Establish normality and avoid wasteful journeys for pregnant women, and for infants and children and their parents.
- Facilitate early counselling when clinical problems were identified;
- Reduce costs associated with medical and nursing time in both district and specialist units, and with NHS transport services (taxis, ambulances);
- Promote training and education of doctors, nurses and ultrasonographers in district hospitals.

B.1 Perspective adopted for the economic evaluation

The economic evaluation was designed as a cost consequences analysis from the perspective of the NHS. Account would also be taken of the expenditure incurred by patients or their families when first in contact with the specialist service. Thus the project set out to identify any differences in the relevant cost and consequences between using, and not using, telemedicine. Jacklin and colleagues adopted the same approach in their economic evaluation of teleconsultations for hospital outpatient advice in London and Shrewsbury [Jacklin et al, 2003].

This Appendix is Chapter 2 from the First Report. References are listed at the end of the Appendix.

The economic evaluation aimed to:

i) Identify and value the total change in direct NHS costs and direct non-medical costs associated with the introduction of telemedicine in the provision of specialist advice in managing fetal and paediatric cardiology cases;

ii) Assess at defined time intervals the health related quality of life of patients receiving telemedicine and patients not receiving telemedicine using health status measurement instruments.

Economic modelling techniques would be used to synthesise the data on costs, survival and health related quality of life to establish the cost effectiveness of introducing telemedicine.

B.2 Selection of the district hospitals

In 2000, two paediatric cardiologists in the TelePaed Project team (MR and RF) held outreach clinics in 19 district general hospitals (DGH) and these hospitals formed the sample frame for the selection of the project hospitals. They were assessed according to:

i) the numbers of deliveries in their obstetric units in 1999 (as a proxy indicator of volumes of cases newly diagnosed with congenital heart disease);

ii) their distance from the specialist hospital (outside inner London);

iii) the presence in the hospital of a consultant paediatrician with a particular interest in paediatric echocardiology;

iv) an expectation that the paediatric directorate would welcome the introduction of telemedicine and space could be found for holding remote consultations.

Since only four district hospitals were being recruited, the selection focused on hospitals with relatively large obstetric caseloads (over 3500 deliveries annually) to ensure the analyses were based on adequate numbers.

Three hospitals in which MR held outreach clinics and one attended by RF were identified as 'candidate' hospitals. After being approached informally by the respective specialist, the lead consultant paediatrician or neonatologist in each hospital was sent a letter from the project director at Brunel in May 2000 inviting the hospital to join the project under the following circumstances:

- Two hospitals would act as intervention sites and receive telemedicine equipment, and two would act as control sites. Later, after the fieldwork was completed, the controls would also be offered telemedicine equipment.
- The hospitals would be paired geographically, and the hospitals in each pair would be allocated as intervention or control sites in a randomised manner.

- The duration of fieldwork would be 18 months and thus the control hospitals would receive their telemedicine equipment early in 2002;
- The telemedicine equipment would be supplied by the project, but the hospitals would incur, as non-research costs, the call charges for the teleconsultations;
- Prior to the introduction of the telemedicine equipment, selected staff in all four hospitals would undergo additional training in fetal ultrasonography and paediatric echocardiography.

The four candidate hospitals were agreeable to these conditions. However, when Brunel researchers (RD and GW) then visited the hospitals, they realised that at one hospital the trolley-mounted telemedicine equipment would have to be wheeled outdoors when being transferred between the paediatric outreach clinic and the neonatal unit and obstetric department. So a fifth hospital was chosen. The four district hospitals that participated in the project were between 35 and 65 miles from the specialist centre and they have been anonymised in this report.

When preparing the commercial tender for the telemedicine equipment, it became apparent that the price structure favoured purchasing four telemedicine packages in a single order. The project team decided therefore to provide the control hospitals their equipment at the same time as the intervention hospitals on the understanding that it could be used for other purposes but not for patients involved in this project. The team felt this offer would help to sustain the goodwill of the control hospitals during the fieldwork period.

B.3 Randomisation of the hospitals

For the randomisation, the participating hospitals were paired according to current practice for obtaining fetal medicine advice:

Pair 1 DGH1 and DGH2 (having paediatric links only with the telemedicine centre).

Pair 2 DGH3 and DGH4 (having both fetal and paediatric links with the centre).

Using a random number generator, a statistician in Brunel who was independent of the project team and blinded of any preferences within the project, allocated the hospitals as:

Intervention hospitals:	DGH1 and DGH4
Control hospitals:	DGH2 and DGH3.

B.4 Research governance

Ethical approval for the project was obtained from a multi-centre research ethics committee and the relevant local research ethics committees for the district hospitals and the specialist centre. Honorary non-medical contracts were issued by the hospital trusts to RD and GW to enable them to liaise with medical record officers. The project's audit database was registered with the national Data Protection Registrar.

B.5 Plan of investigation

The project had four substantive fieldwork phases.

i) A three-month baseline phase (from May to July 2001) during which audit data were collected on current practice in the four district hospitals and the telemedicine equipment was installed;

ii) A six-month intervention phase (from August 2001 to January 2002) when the two intervention hospitals used the telemedicine equipment;

iii) A six-month service phase (from February to July 2002) when all four hospitals used the telemedicine equipment;

iv) A three-month follow-up phase (from August to October 2002) in which the audit databases were completed.

The service phase, when the control hospitals were permitted to join the intervention hospitals in using the telemedicine equipment for fetal and paediatric cardiac purposes, was introduced after the intervention phase had run for five of the nine planned months and a progress report showed that fewer than 10 telemedicine face to face consultations with patients had been conducted. The usefulness of the economic evaluation would have been limited if the pattern of use was unchanged over the remaining months of the fieldwork.

B.6 The telemedicine equipment

The telemedicine packages allowed the district clinicians flexibility over the methods of information transmission to the specialist centre; that is, they could:

Hold face to face consultations with patients (and parents) present and transmit live fetal ultrasound images or echocardiograms and heart sounds

Hold face to face discussions while transmitting pre-recorded fetal ultrasound images or echocardiograms.

The telemedicine systems were designed for use with ISDN-6 lines (i.e. three pairs of ISDN lines, each line being 64 Kb). Each DGH received an equipment package consisting of a video conferencing system, a videotape recorder, an object camera and an electronic stethoscope sender. Specifications of the equipment are shown in Table B.1. The telemedicine suite in the specialist centre was already comprehensively equipped, but it was necessary to buy an electronic stethoscope receiver.

Table B.1 Telemedicine equipment packages supplied to the district hospitals

Tanberg video conferencing system incorporating:
- 384 Kb/s computer (CODEC) with camera, ultrasound and VCR inputs
- Pan.tilt zoom camera
- Loudspeaker with volume control
- Microphone
- VHS medical grade video recorder
- Peripheral items (e.g. mains distribution and ISDN cables)

Tele-medical trolley (fitted with the above items)
Two monitors exceeding 20 inches suitable for wall mounting
Document / object camera visualiser
Electronic stethoscope sender

Satelcom (UK) Ltd supplied the equipment, apart from the electronic stethoscope senders and receiver, which were obtained from American Medical Development in Lowell, MA. The hospitals 'tailored' the installation of the packages to suit the layout of their neonatal and paediatric units.

B.7 Training arrangements

a) *Telemedicine.* The telemedicine co-ordinator from the specialist centre supervised the installation of the equipment in the district hospitals and trained the lead consultants and other staff members in its use. The equipment supplier also provided some training.

b) *Ultrasonography and echocardiography.* Senior sonographers from the obstetric departments attended sessions held by HG in London on fetal heart scanning. HG also attended an intervention DGH for a further training session. Consultant paediatricians and neonatologists received echocardiography tuition from MR in specially organised sessions in London. The fetal ultrasound training took place during the baseline phase. The echocardiography training was delayed until new echocardiogram machines had been installed in the specialist centre and it was held early in the implementation phase.

B.8 The roles of project facilitators and telemedicine co-ordinator

Project facilitators were employed in the district hospitals on a half-time basis. They were responsible for recording clinical and resource items in the project's audit database designed specifically for the project – laptop computers were provided – and for administering postal surveys to pregnant women and the parents of paediatric patients. The computers allowed the facilitators flexibility to collect information in different hospital departments. The facilitators were already working in the hospitals (in the obstetric, neonatal or paediatric units) so they continued to be employed by the NHS Trusts although their activities were co-ordinated by the Brunel research team. The telemedicine co-ordinator in the specialist centre audited the clinical events of district patients referred to the centre and entered the items in a database.

During the fieldwork the telemedicine co-ordinator advised the district hospitals on technical matters relating to the operation of the equipment, provided additional training, and facilitated telemedicine link-ups between the district clinicians and the specialists.

B.9 Project co-ordination

At the beginning of the baseline phase lunchtime seminars were held in the district hospitals, when GW and RD explained the purpose of the project, the role of telemedicine, and introduced the local project facilitator. The audiences included paediatric, neonatal and obstetric medical and nursing staff, sonographers and business managers. Other visits were made during the fieldwork phases by the Brunel project team. At no time, however, did the Brunel researchers attempt to influence the lead consultants on how they might utilise the equipment routinely (e.g. for live consultations with patient present or via the store and forward method). In the event, the four hospitals, in consultation with the respective specialists in the centre, adopted different patterns of regular use.

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APPENDIX C

HANDLING THE NHS RESOURCE DATA

APPENDIX C: HANDLING THE NHS RESOURCE DATA#

C.1 Deriving weights for the district hospitals' unit costs

It was not possible to obtain all the required unit cost data from all district hospitals mainly because the costing information in the finance departments was held at a level of aggregation that was higher than required for this project. Moreover, among the costs there were some marked inter-hospital variations. To minimise the distorting effect from outlying costs, weighted unit costs were used for attributing cost per resource item rather than mean costs. This approach was used in the economic evaluation of the liver transplantation programme in England and Wales undertaken at Brunel. [Longworth et al, 2003]

Table C1: Weightings used when unit costs were available for all four district hospitals

Hospital	DGH1	DGH2	DGH3	DGH4
Resource use incurred by pregnant women only				
Total eligible patients	11	34	76	127
Weight applied	0.044	0.137	0.306	0.512
Resource use incurred by newborn babies only				
Total eligible patients	7	8	17	8
Weight applied	0.175	0.200	0.425	0.200
Resource use incurred by older children only				
Total eligible patients	59	69	54	34
Weight applied	0.273	0.319	0.250	0.157
Resource use incurred by all eligible patients				
Total eligible patients	77	11	147	169
Weight applied	0.153	0.220	0.292	0.335
Resource use incurred by newborn babies and older children				
Total eligible patients	66	77	71	42
Weight applied	0.258	0.301	0.277	0.164

The weights for the unit costs were derived according to the total number of referred patients to specialists – see Table C1. The table shows the weights used for items of resource use for which all four hospitals provided their unit costs. To illustrate: for a resource item used only by pregnant women, such as an anomaly scan, the weights in row 4 of the table were applied when calculating the unit costs. For resource items applicable to both newborn babies and older children, such as a chest x-ray, then the relevant weights in row 16 of the table were

References are listed at the end of this Appendix.

applied. For resource items with fewer unit costs provided (i.e. from two or three finance departments), the weights for the hospitals were recalculated based on the overall distribution of eligible cases across the two/three hospitals. Finally, where there was only one available unit cost for a resource item, that cost was applied to all four hospitals.

C.2 Calculating weighted unit costs for all district hospitals

For each item of resource use, the unit cost supplied by a finance department was multiplied by the appropriate weight for the hospital to give a 'weighted' cost. The weighted costs for the hospitals were then summed to give an overall weighted unit cost for the resource item. Finally, the weighted unit cost for each item of resource use was attributed to all eligible patients who used the item regardless of the district hospital they were from. An illustration of how the weights were applied can be seen in Box A.

Box A: Illustration of how the weights were applied.

The hypothetical unit costs of a anomaly scan supplied by the finance departments are: DGH1, £40; DGH2, £30; DGH3, £20; and DGH4, £25. These costs are multiplied by the respective weights presented in Table C1:

£40 x 0.044, £30 x 0.137, £20 x 0.306, and £25 x 0.512.

The products are then summed to arrive at a weighted unit cost for the scan - £24.79. The unweighted mean of the four unit costs supplied by the departments was slightly higher at £28.75.

The hypothetical unit costs of a chest x-ray supplied by the finance departments are: DGH1, £20; DGH2, £15; DGH3, £12; and DGH4, £18. These costs are multiplied by the respective weights presented in Table C1:

£20 x 0.258, £15 x 0.301, £12 x 0.277, and £18 x 0.164.

The weighted unit cost for the x-ray examination - £15.95. The unweighted mean cost was slightly higher at £16.25.

If only the first three hospitals had provided costs for the chest x-ray, the weights would have been:

DGH1 0.308; DGH2, 0.360; DGH3, 0.332;

and the weighted unit cost £15.54 compared with the unweighted mean unit cost of £15.67.

C.3 Deriving a mean cost for the specialist hospital unit costs

For pregnant women, unit costs were provided from two specialist finance departments. If both hospitals provided a unit cost for an item, an average cost was calculated; if only one cost was available, it was used in the analyses. The derived costs were attributed to all women regardless of which London hospital they went to. For newborn babies and older children, only one specialist hospital provided unit costs. These unit costs were applied to all resource use incurred by these patients. For babies who occupied a cot in both a district hospital and a specialist unit on the same day, the unit costs for the cot day were pro-rated.

C.4 Discounting costs

No discounting was undertaken because discounting typically applies to costs incurred after the first year of study, whereas for the cost analyses in this report, the maximum follow-up for all eligible patients was 6 months.

C.5 Costing medical staff time

The costs for medical staff were based on NHS salary scales published by the Department of Health. Hourly rates were calculated by the number of hours expected to work each year, taking annual leave and bank holidays into account [Netten and Curtis, 2002]. These hourly rates were then applied to the duration that it took the medical staff to carry out the relevant task (e.g. telemedicine consultation). The calculations included the time spent carrying out the task and documenting the task or result in patient's clinical notes.

C.6 Calculation of telemedicine costs for all DGHs

i) *Telemedicine equipment and installation* – Annual equivalent costs for the telemedicine package, including VAT and installation for each district hospital was calculated separately and were estimated over the expected lifetime of the equipment [HM Treasury, 1980]. We assumed a lifetime of 5 years for the telemedicine equipment in line with assumptions in another study of telemedicine services in outpatient clinics [Jacklin et al, 2003] with a discount rate of 3.5% as recommended by the Treasury [HM Treasury, 2003]. We then divided the annual equivalent cost for each DGH by the total number of teleconsultations (fetal, neonate and older children) in each hospital during the study period to derive a cost per equipment and installation per consultation.

ii) *Telephone bills for the ISDN-6 lines* – The full cost of the telephone bills (line rental and call charges) incurred over the 12 months for DGH2 and DGH3 was divided by the total number of teleconsultations in each hospital. The full cost of the telephone bills (line rental and call charges) incurred over the six months for DGH1 and DGH4 was divided by the total number of teleconsultations in each hospital.

iii) *Telemedicine co-ordinator costs* – These costs covered the time spent by the co-ordinator from the specialist centre on briefing, installation and training in the district hospital and return travel from the specialist hospital. The full cost for DGH2 and DGH3 was divided by the total number of teleconsultations in each hospital. Whereas for DGH1 and DGH4 six-month costs were calculated and then divided by the total number of teleconsultations in each hospital.

C.7 Calculation of specialist transfer costs.

Two NHS ambulance services provided costs for ambulances used in neonatal transfers, taking account of the distances travelled when making return journeys between each local hospital and a London hospital. DGH3, which had its own retrieval team, provided the cost for a neonatal transfer team, inclusive of a travelling incubator, drugs, disposable items, and medical and nursing staff time. The overall cost of a transfer of a newborn baby to a London hospital was multiplied by the weighting for each district hospital in order to obtain a weighted unit cost for the transfer. This weighted cost was then applied to each transfer, regardless of which hospital the baby travelled from. For older children transferred by ambulance, the same method was used for obtaining a weighted unit cost for each transfer. However, the cost components did not include the expenses associated with a retrieval team and equipment used with neonates.

C.8 Analytical approach

a) *Statistical tests.* Analysis of variance (ANOVA) and t tests were used to explore the differences in costs between referral methods, district hospitals and patient groups, unless stated otherwise in the text. All statistical tests were two sided. A p-value of less than 0.05 was considered to be statistically significant (unless otherwise stated). The statistical computer packages of SPSS® and Stata Version 8 were used. [StataCorp, 2003].

b) *Bootstrapping of cost data.* As the distributions of patient costs were skewed, bias adjusted non-parametric bootstrapping were performed in order to generate confidence limits around the means. Bootstrapping is a simulation technique that takes repeated samples of data, with replacement and, in the absence of any other data from the population, gives a guide to its distribution [Manly, 1997]. Non-parametric bootstrapping was performed using the S-PLUS software taking 5,000 iterations of the data. [S-PLUS, 2000]

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APPENDIX D

FURTHER ANALYSES OF THE QUALITY OF LIFE SURVEYS

APPENDIX D: FURTHER ANALYSES OF THE QUALITY OF LIFE SURVEYS

A) Surveys of pregnant women

Initial questionnaires were sent to women in DGH1 and DGH3 who were entered in the project database between October 2001 and July 2002. The project facilitators in the hospitals posted the questionnaire packages at least two weeks after the women had undergone their anomaly scan. The women returned the completed questionnaire and a consent form to the project office at Brunel University, using a pre-addressed, pre-paid envelope. Each questionnaire had a code number entered on the front. The project team informed the facilitators weekly of the code numbers for the incoming questionnaires, so that reminder questionnaires could be sent to non-respondents after three weeks. Using the postal details on the consent forms, follow-up questionnaires (and reminder questionnaires) were sent from the project office at Brunel, 13 weeks after receiving the initial questionnaire. The project office held no information on the progress of the women's pregnancies.

The completed project database showed that the mean gestation in the women's pregnancies was 25 weeks by the time their initial questionnaires were returned. For the follow-up survey, the mean gestation was 39 weeks (i.e. just before a pregnancy reaches full term) by the time the questionnaires were received. Each questionnaire asked for the date when the questionnaire was completed. By checking these dates against the database, we concluded that over half (56%) of the follow-up questionnaires were completed after the women were delivered. So the follow-up questionnaire were analysed in two groups - pre-delivery and post-delivery - to allow for any differences in quality of life the women may have experienced as a consequence of giving birth.

Questionnaires were sent to 63 women referred to specialists from DGH1 and DGH3 during the 10-month survey and replies were received from 37 (58.7%): 26 from 43 women assessed via telemedicine and 11 from 20 women who travelled to London.

The following tables (D1 to D6) show the results for the HADS anxiety and depression instrument and the EQ-5D instrument according to the method by which the women were assessed by the specialists – via telemedicine or by travelling directly to London for a face-to-face consultation. The bar charts in Figure D1 show the ratings for each of the five dimensions in the EQ-5D instrument.

Table D1: Mean and median anxiety scores for initial and follow-up surveys

Mean and median anxiety scores for each survey	Type of referral	
	Telemedicine	Direct
Initial questionnaire		
Number	26	11
Mean (SD)	8 (3)	8 (4)
Median	9	8
IQR	5 to 10	4 to 12
Pre-delivery follow-up questionnaire		
Number	7	4
Mean (SD)	8 (3)	8 (2)
Median	7	8
IQR	6 to 10	7 to 10
Post-delivery follow-up questionnaire		
Number	12	1
Mean (SD)	7 (3)	7 (n/a)
Median	7	7
IQR	5 to 9	7 to 7

(Kruskal Wallis statistics): Initial: χ_1^2 = 0.06, p = 0.815; Pre-delivery; χ_1^2 = 0.33, p = 0.565; Post-delivery: χ_1^2 = 0.07, p = 0.788

Table D2: Anxiety levels observed in the initial and follow-up surveys

Anxiety categories	Type of referral	
	Telemedicine	Direct
Initial questionnaire		
Number	26	11
No anxiety (0-7)	10 (38.5%)	4 (36.4%)
Possible major anxiety (8-10)	10 (38.5%)	4 (36.4%)
Probable major anxiety (11-21)	6 (23.0%)	3 (27.3%)
Pre-delivery follow-up questionnaire		
Number	7	4
No anxiety (0-7)	4 (57.1%)	2 (50.0%)
Possible major anxiety (8-10)	2 (28.6%)	2 (50.0%)
Probable major anxiety (11-21)	1 (14.3%)	0 (0.0%)
Post-delivery follow-up questionnaire		
Number	12	1
No anxiety (0-7)	8 (66.7%)	1 (100.0%)
Possible major anxiety (8-10)	2 (16.7%)	0 (0.0%)
Probable major anxiety (11-21)	2 (16.7%)	0 (0.0%)

(Chi-squared statistics): Initial: χ_2^2 = 0.07, p = 0.964; Pre-delivery: χ_2^2 = 0.92, p = 0.632; Post-delivery: χ_2^2 = 0.48, p = 0.786

Table D3: Mean and median depression scores for initial and follow-up surveys

Mean and median depression scores	Type of referral	
	Telemedicine	Direct
Initial questionnaire		
Number	26	11
Mean (SD)	5 (3)	4 (3)
Median	5	3
IQR	1 to 7	2 to 7
Pre-delivery follow-up questionnaire		
Number	7	4
Mean (SD)	7 (4)	3 (2)
Median	8	3
IQR	4 to 9	1 to 5
Post-delivery follow-up questionnaire		
Number	12	1
Mean (SD)	5 (4)	3 (n/a)
Median	4	3
IQR	2 to 7	3 to 3

(Kruskal Wallis statistics): Initial: χ_1^2 = 0.07, p = 0.788; Pre-delivery: χ_1^2 = 2.93, p = 0.087; Post-delivery: χ_1^2 = 0.02, p = 0.892

Table D4: Depression levels observed in the initial and follow-up surveys

Depression categories	Referred women	
	Telemedicine	Direct
Initial questionnaire		
Number	26	11
No depression (0-7)	22 (84.6%)	9 (81.8%)
Possible major depression (8-10)	3 (11.5%)	2 (18.2%)
Probable major depression (11-21)	1 (3.9%)	0 (0.0%)
Pre-delivery follow-up questionnaire		
Number	7	4
No depression (0-7)	3 (42.9%)	4 (100.0%)
Possible major depression (8-10)	3 (42.9%)	0 (0.0%)
Probable major depression (11-21)	1 (14.3%)	0 (0.0%)
Post-delivery follow-up questionnaire		
Number	12	1
No depression (0-7)	9 (75.0%)	1 (100.0%)
Possible major depression (8-10)	1 (8.3%)	0 (0.0%)
Probable major depression (11-21)	2 (16.6%)	0 (0.0%)

(Chi-squared statistics): Initial: χ_2^2 = 0.68, p = 0.711; Pre-delivery: χ_2^2 = 3.59, p = 0.166; Post-delivery: χ_2^2 = 0.33, p = 0.850

Table D5: EQ-5D visual analogue assessment of health states in the initial and follow-up surveys

EQ-5D visual analogue scale	Type of referral	
	Telemedicine	Direct
Initial questionnaire		
Number	24	11
Mean (SD)	76 (21)	78 (13)
Median	80	80
IQR	70 to 90	70 to 90
Pre-delivery follow-up questionnaire		
Number	8	4
Mean (SD)	78 (18)	83 (5)
Median	80	80
IQR	65 to 93	80 to 85
Post-delivery follow-up questionnaire		
Number	12	1
Mean (SD)	83 (9)	80 (n/a)
Median	88	80
IQR	75 to 90	80 to 80

(Kruskal Wallis statistics): Initial: χ_1^2 = 0.03, p = 0.872; Pre-delivery: χ_1^2 = 0.03, p = 0.864; Post-delivery: χ_1^2 = 0.47, p = 0.494

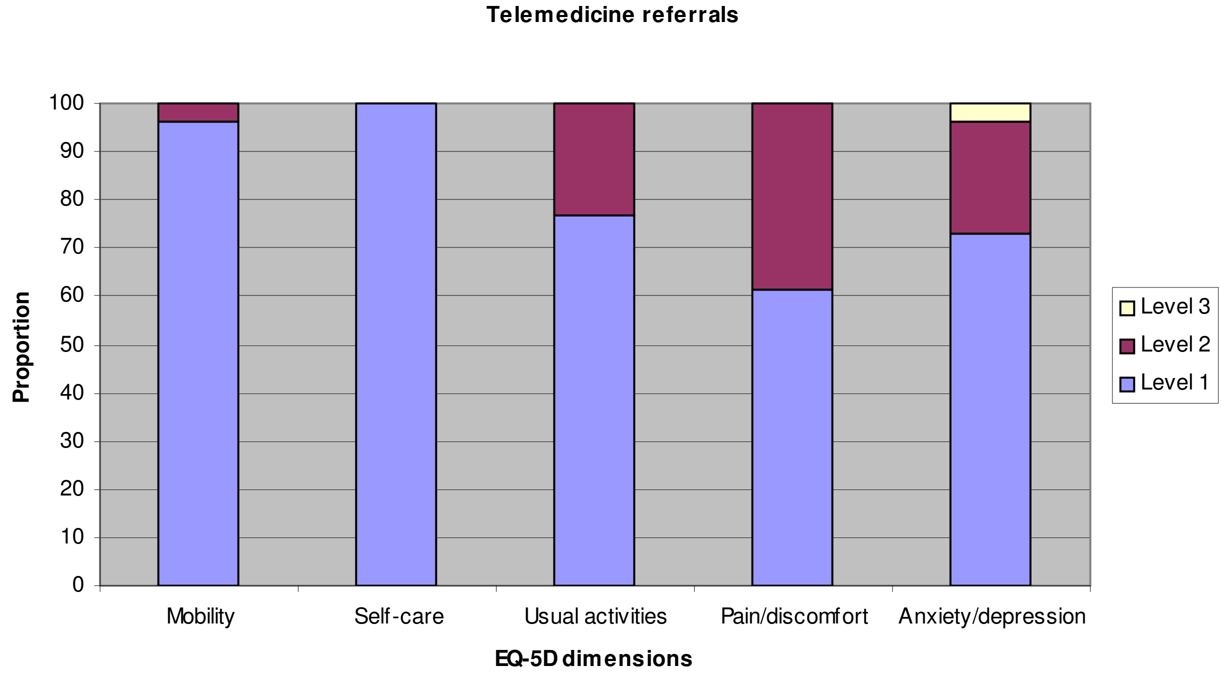
Table D6: EQ-5D tariff for health states in the initial and follow-up surveys

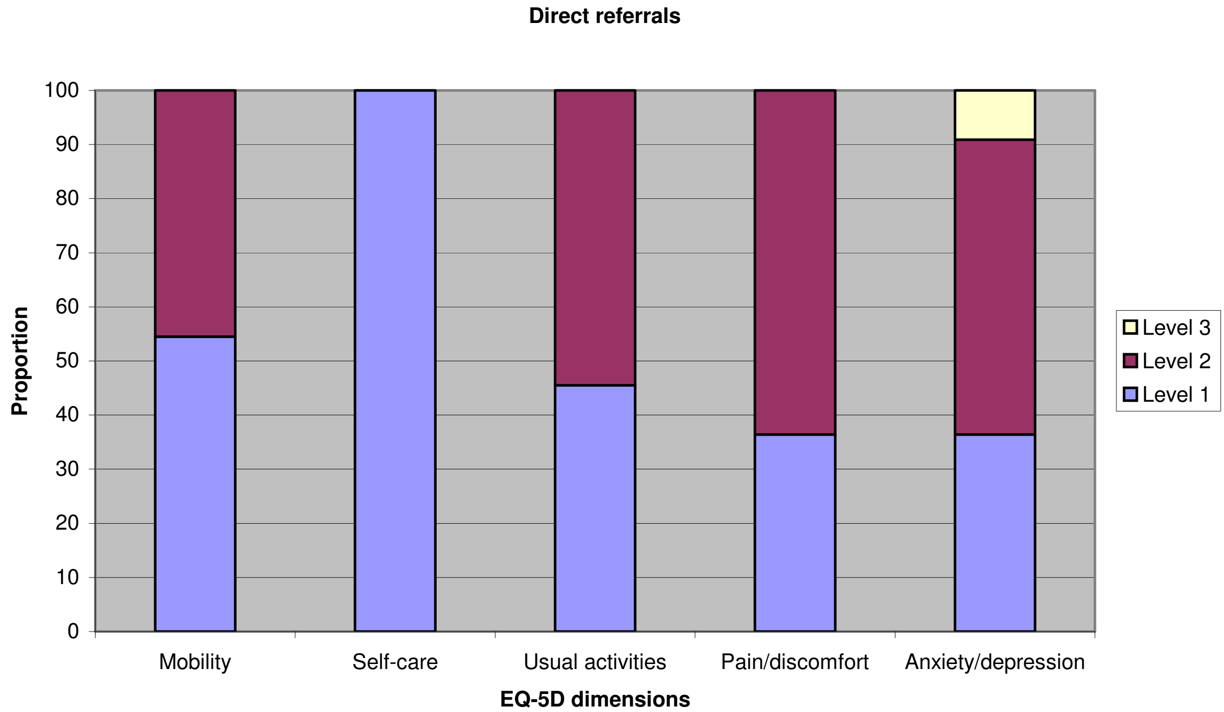
EQ-5D tariff based on 5 dimensions	Type of referral	
	Telemedicine	Direct
Initial questionnaire		
Number	26	11
Mean (SD)	0.86 (0.14)	0.72 (0.22)
Median	0.83	0.76
IQR	0.80 to 1.00	0.62 to 0.85
Pre-delivery follow-up questionnaire		
Number	8	4
Mean (SD)	0.81 (0.13)	0.78 (0.20)
Median	0.79	0.80
IQR	0.71 to 0.92	0.66 to 0.91
Post-delivery follow-up questionnaire		
Number	12	1
Mean (SD)	0.86 (0.13)	0.80 (n/a)
Median	0.80	0.80
IQR	0.76 to 1.00	0.80 to 0.80

(Kruskal Wallis statistics): Initial: χ_1^2 = 4.64, p = 0.031; Pre-delivery: χ_1^2 = 0.01, p = 0.932; Post-delivery: χ_1^2 = 0.02, p = 0.889

Figure D1: Ratings for the individual EQ-5D dimensions (Telemedicine = 26 and Direct referral = 11)

Key: Level 1 = No physical problems, no pain or not anxious / depressed;
Level 2 = Some physical problems or moderate pain or anxiety / depression;
Level 3 = Physical inability or extreme pain or anxiety / depression.





B) Surveys relating to children

Health-related quality of life (QUALIN) for children under two years

Two versions of the QUALIN instrument were used in the questionnaires that mothers completed; a version for infants under one year, and a version for children aged between 1 and 2 years. The statements in the two versions were either identical (e.g. "This baby is bright" or "This child is bright") or similar in meaning (e.g. "This baby cries as soon as he/she is left alone" or "This child finds it hard to leave his/her parents"). Even though combining responses from differing versions of an instrument is not advisable, we took this step because the numbers of eligible questionnaires were so few for the separate age groups.

Table D7 shows the comparative results from the QUALIN questionnaires sent out initially and at follow up, three months later. The initial questionnaires were completed for 3 children in the telemedicine group and 13 children in the non-telemedicine group. Although the median QUALIN score of 32 for the telemedicine children was higher than the median of 28 for the non-telemedicine comparators, there was no statistically significant difference as both groups were generally experiencing a favourable quality of life. Three months later the median scores for 2 telemedicine children and 12 non-telemedicine children were slightly better, again the differences being non-significant.

Table D7: QUALIN scores for new children under 2 years recorded in the initial and follow-up questionnaires

Timing of questionnaire	QUALIN overall scores	
	Telemedicine	**Non-telemedicine**
Initial		
Number	3	13
Median	32†	28†
IQR	26 to 33	24 to 31
First follow-up		
Number	2	12
Median	34††	29††
IQR	28 to 40	21 to 36

† Kruskal Wallis χ^2_1 = 0.37, p = 0.544

†† Kruskal Wallis χ^2_1 = 0.81, p = 0.846

Health-related quality of life (PedsQL™) for children aged over two years

Forty-two initial questionnaires containing the PedsQL™ v.4 instrument were completed for newly referred children, 9 (21%) having experienced telemedicine. Two parental versions of the instrument were used: versions for children 2 to 4 years, and for children 5 years and older. Once again, because of the relatively small numbers of responses relating to children who had experienced telemedicine, it was decided to amalgamate the responses, scientific reservations notwithstanding. Three of the four domains (physical functioning, emotional functioning and social functioning) were 8- or 5-item scales and they were worded similarly in the two versions. The fourth domain on nursery/school functioning had differing numbers of items in the two versions and it was omitted from the analyses.

Table D8 shows the comparative results for the three domains. In both the initial and three-month follow-up surveys the medians for telemedicine children were slightly higher for each domain. However, the differences were not statistically significant. Physical functioning was the only domain for which improvements in both groups were recorded when followed up after three months.

Table D8: PedsQL[TM] domains for new children aged over two years recorded in the initial and follow-up questionnaires

Timing of questionnaire	Physical functioning		Emotional functioning		Social functioning	
	Tele-medicine	Non tele-medicine	Tele-medicine	Non tele-medicine	Tele-medicine	Non tele-medicine
Initial						
Number	9	33	9	33	9	33
Median	700†	675†	350‡	325‡	500#	450#
IQR	550 to 775	500 to 750	325 to 400	250 to 400	350 to 500	325 to 500
First follow-up						
Number	7	18	7	18	7	18
Median	750††	738††	375‡‡	325‡‡	450##	425##
IQR	650 to 775	600 to 775	250 to 400	250 to 375	375 to 500	325 to 500

† Kruskal Wallis $\chi_1^2 = 0.11$, p = 0.746

†† Kruskal Wallis $\chi_1^2 = 0.16$, p = 0.691

‡ Kruskal Wallis $\chi_1^2 = 0.72$, p = 0.397

‡‡ Kruskal Wallis $\chi_1^2 = 0.37$, p = 0.542

Kruskal Wallis $\chi_1^2 = 0.58$, p = 0.446

Kruskal Wallis $\chi_1^2 = 0.96$, p = 0.810

APPENDIX E

BOX PLOTS FOR THE COST ANALYSES

APPENDIX E: BOX PLOTS FOR THE COST ANALYSES

Box plots are presented in this Appendix to demonstrate the magnitude of skewed distributions in the observed patient costs. (A box plot indicates the median value in a dataset, as represented by the solid line through the middle of the box, and if the line is not centred in the box, then the data are skewed. The box, itself, represents the middle 50% of the data (the inter-quartile range). The whiskers (vertical lines) indicate the minimum and maximum data values, unless outliers are present, in which case the whiskers extend to a maximum of 1.5 times the length of the inter-quartile range. The points (dots) beyond the ends of the whiskers are outliers.)

The cases with particularly high observed costs (i.e. the outliers) in the following box plots had mostly received emergency or planned treatment for their congenital heart disease. The unit costs for the procedures (without medical staff time) were:

Catheter examination:	£2325
Catheter procedures:	£4451
Surgical procedures:	£5227-£9017.

A) Box plots of the initial consultation costs

Figure E1 : Cost per patient for the initial consultation for all patients according to referral mode

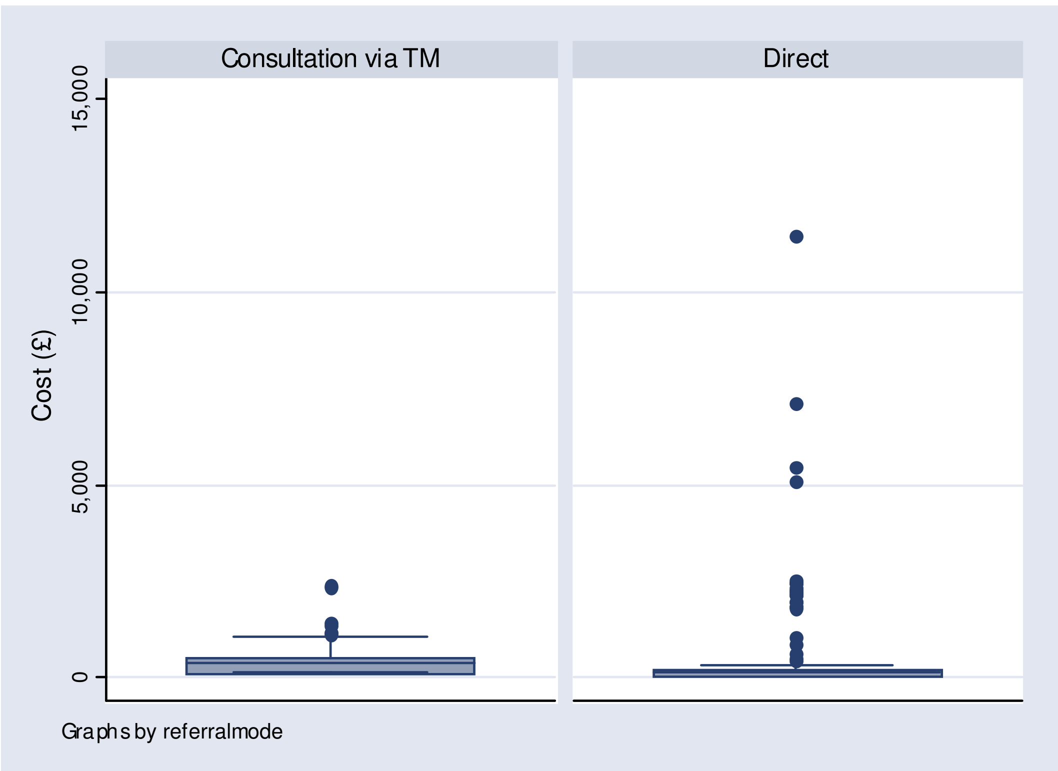


Figure E2a: Cost per patient for initial consultations using the telemedicine service

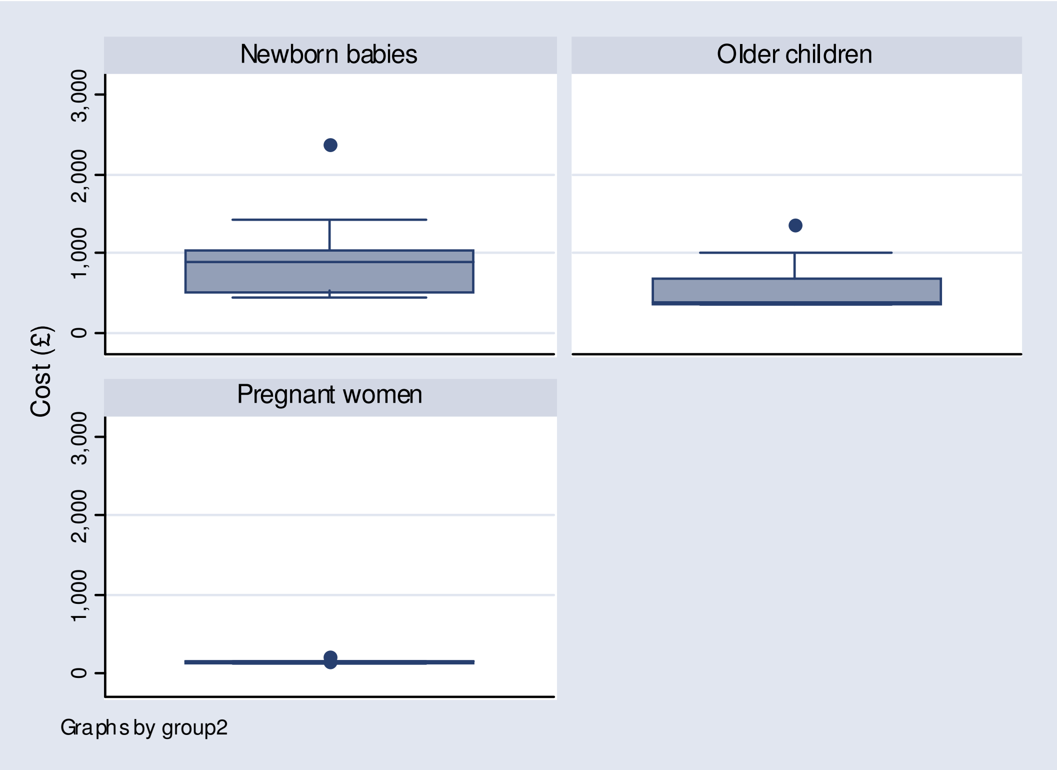
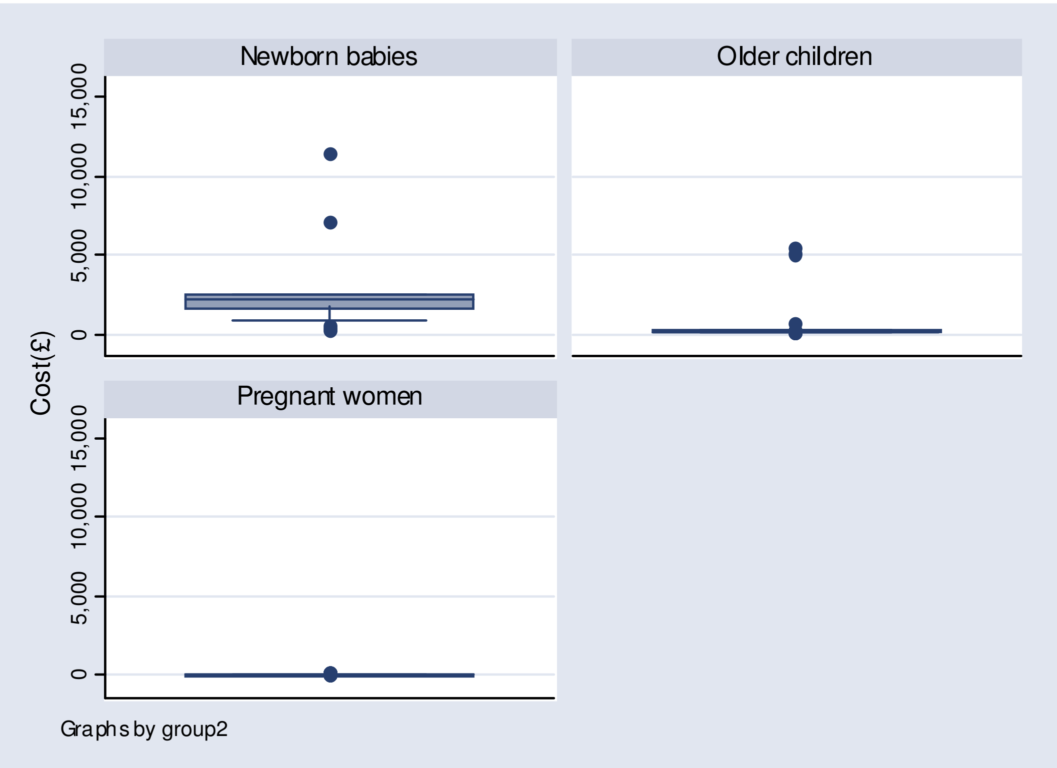


Figure E2b: Cost per patient for initial consultations conducted conventionally



B) Box plots of the 14-day costs

Figure E3: Cost per patient over 14 days for all patients according to referral mode

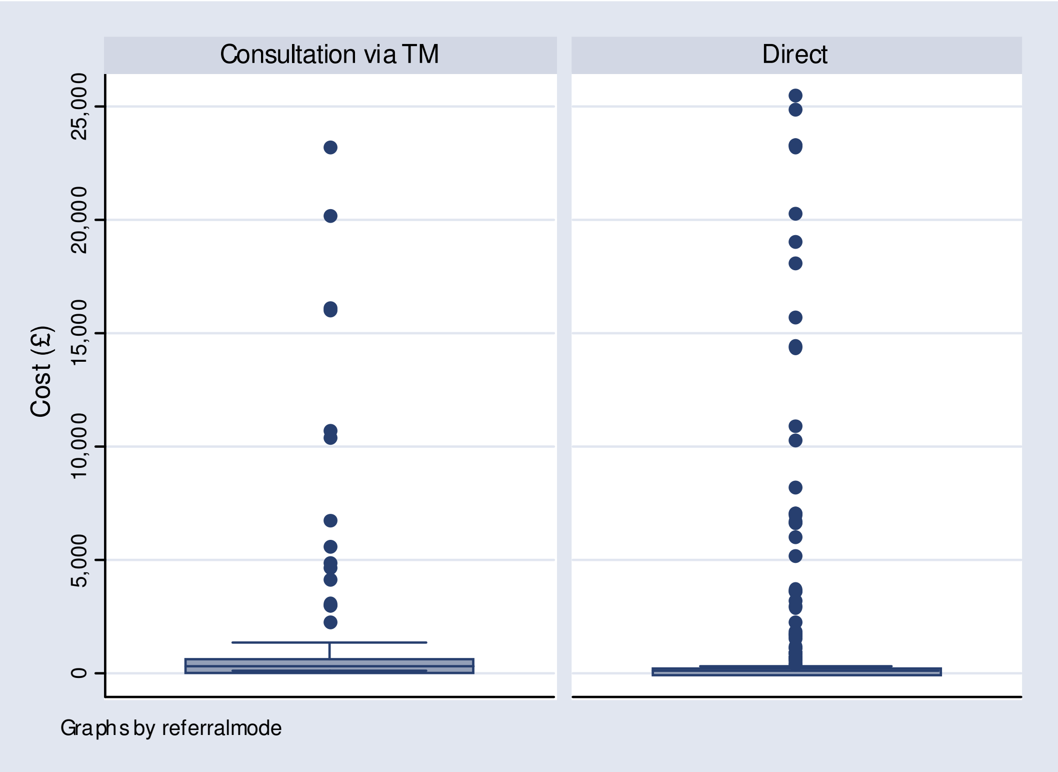


Figure E4a: Cost per patient over 14 days for patients referred using the telemedicine service

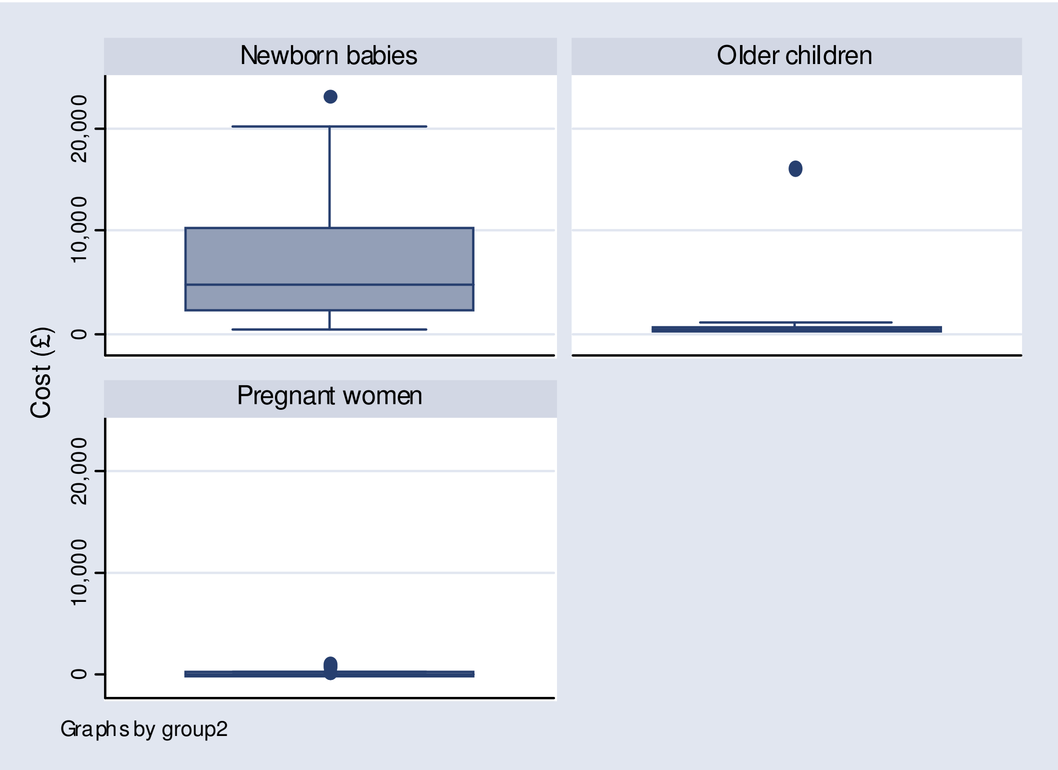


Figure E4b: Cost per patient over 14 days for patients referred conventionally

C) Box plots of the six-month maximum costs

Figure E5: Cost per patient over six months for all patients according to referral mode

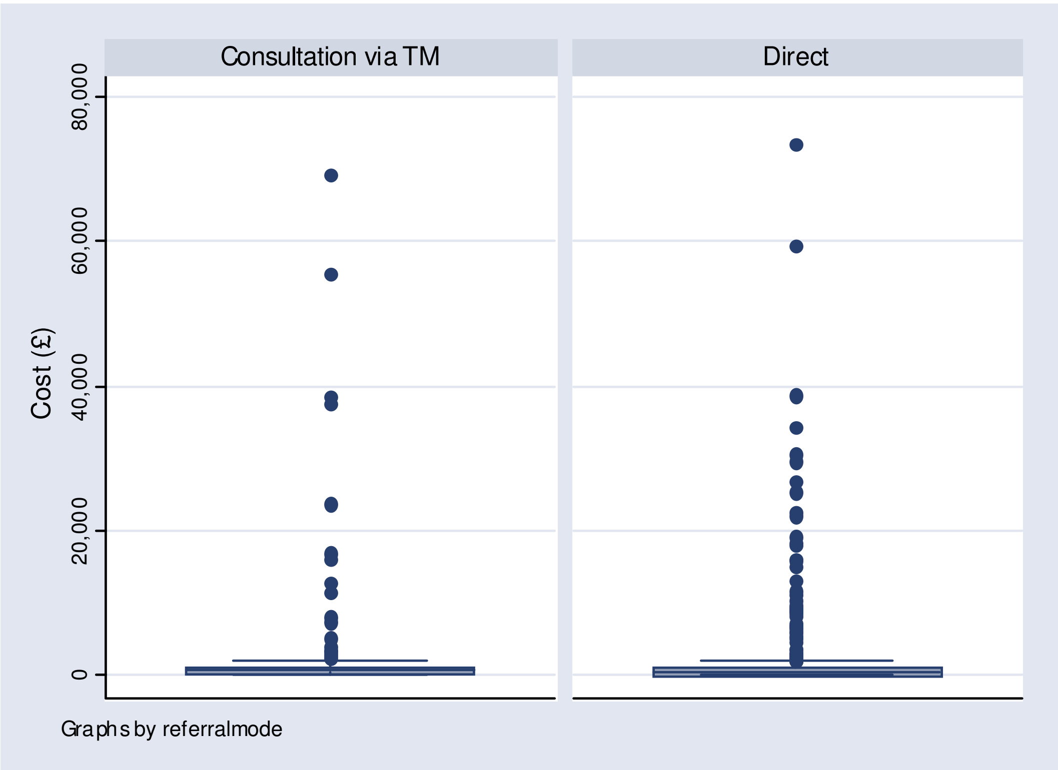


Figure E6a: Cost per patient over six months for patients referred using the telemedicine service

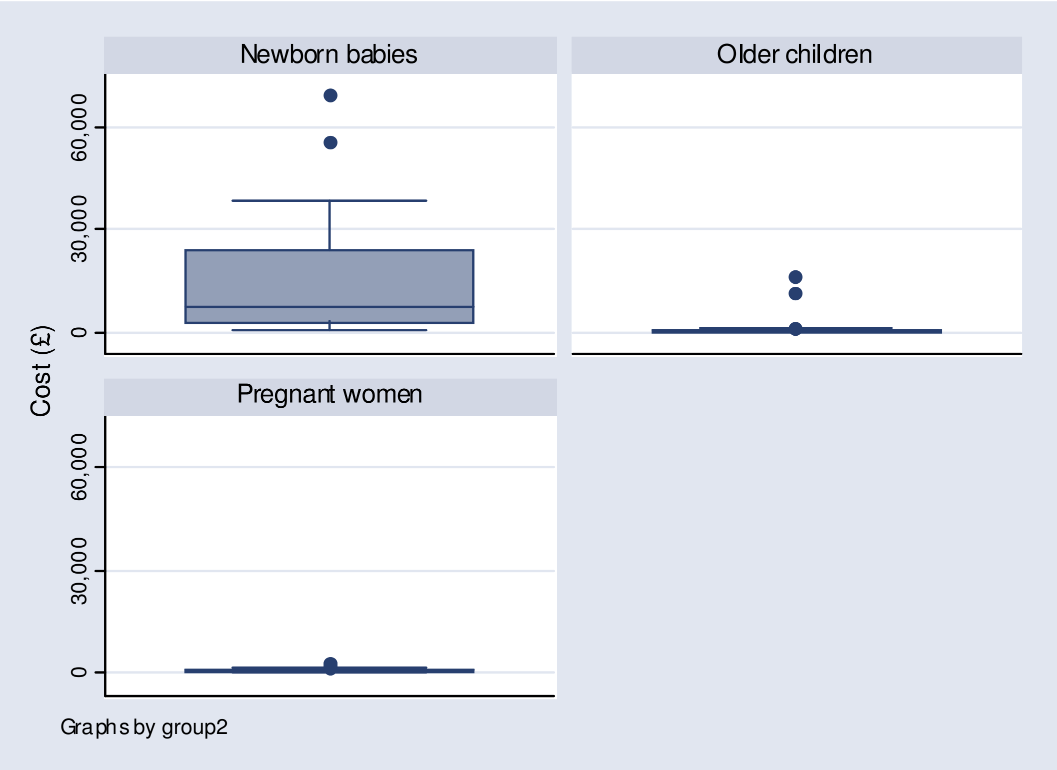
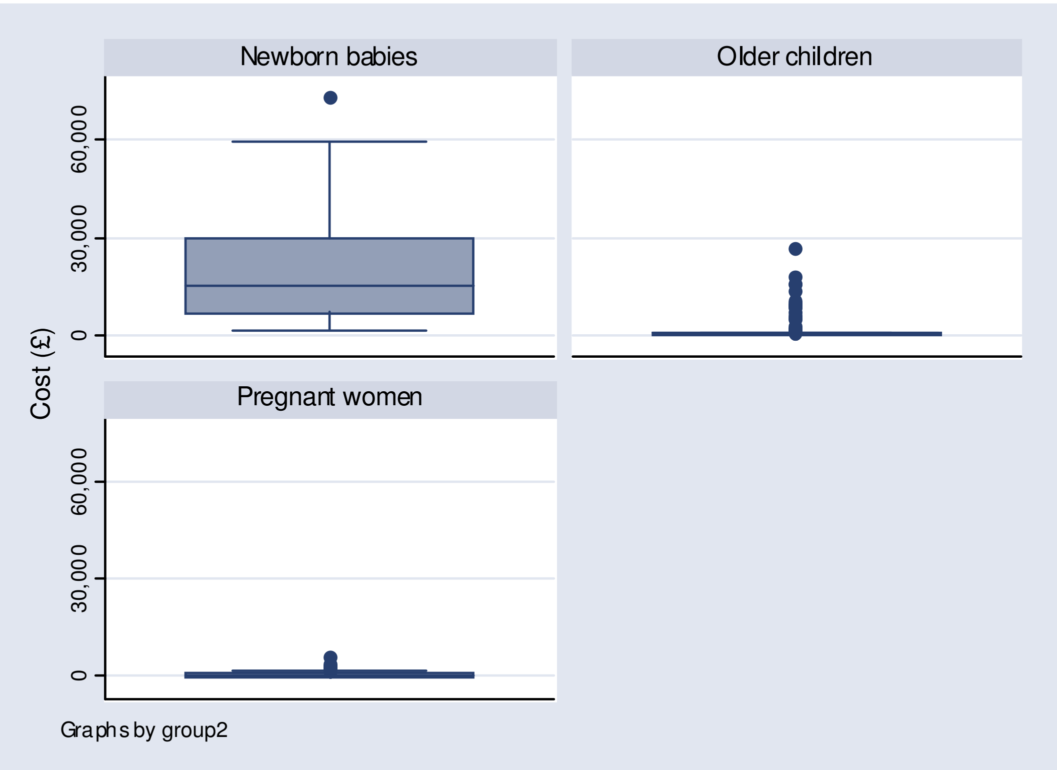


Figure E6b: Cost per patient over six months for patients referred conventionally



D) Telemedicine service costs in two district hospitals

The following table presents the detailed results of the cost analysis for the telemedicine services for the intervention hospitals that had access to the service over 12 months. DGH2 used the service for newborn babies and infants and children, and DGH3 used it for pregnant women and newborn babies. These results are summarised in Figure 1 of the Final Paper.

Table E1 Bootstrapped mean cost per patient for DGH2 covering newborn babies and older children, and DGH3 covering pregnant women and newborn babies

Referral method		Time period		
		Initial consultation	14 days	6 months
DGH2 Newborn babies and older children				
Telemedicine N=38	Mean (SD) 95% CL	£440 (£207) £395 to £549	£898 (£1,912) £480 to £1,983	£1,497 (£3,320) £769 to £3,200
Conventional N=39	Mean (SD) 95% CL	£275 (£452) £173 to £517	£878 (£4,078) £179 to £3,753	£2,431 (£6,520) £999 to £5,713
Test result	t test	t = -2.08, p = 0.041	t = -0.04, p = 0.966	t = 0.80, p = 0.426
DGH3 Pregnant women and newborn babies				
Telemedicine N=61	Mean (SD) 95% CL	£260 (£344) £198 to £390	£1,569 (£4,457) £747 to £3,281	£4,728 (£12,489) £2,060 to £9,192
Conventional N=32	Mean (SD) 95% CL	£982 (£2,356) £439 to £2,486	£3,385 (£7,054) £1,496 to £6,754	£5,513 (£10,018) £2,889 to £10,558
Test result	t test	t = 2.33, p =0.022	t = 1.51, p = 0.134	t = 0.50, p = 0.619

Note: Statistical tests were performed on non-bootstrapped mean costs.

Figure E7: Cost per patient for the initial consultation (DGH2 n=38 telemedicine, 39 direct; DGH3 n=61 telemedicine, 32 direct)

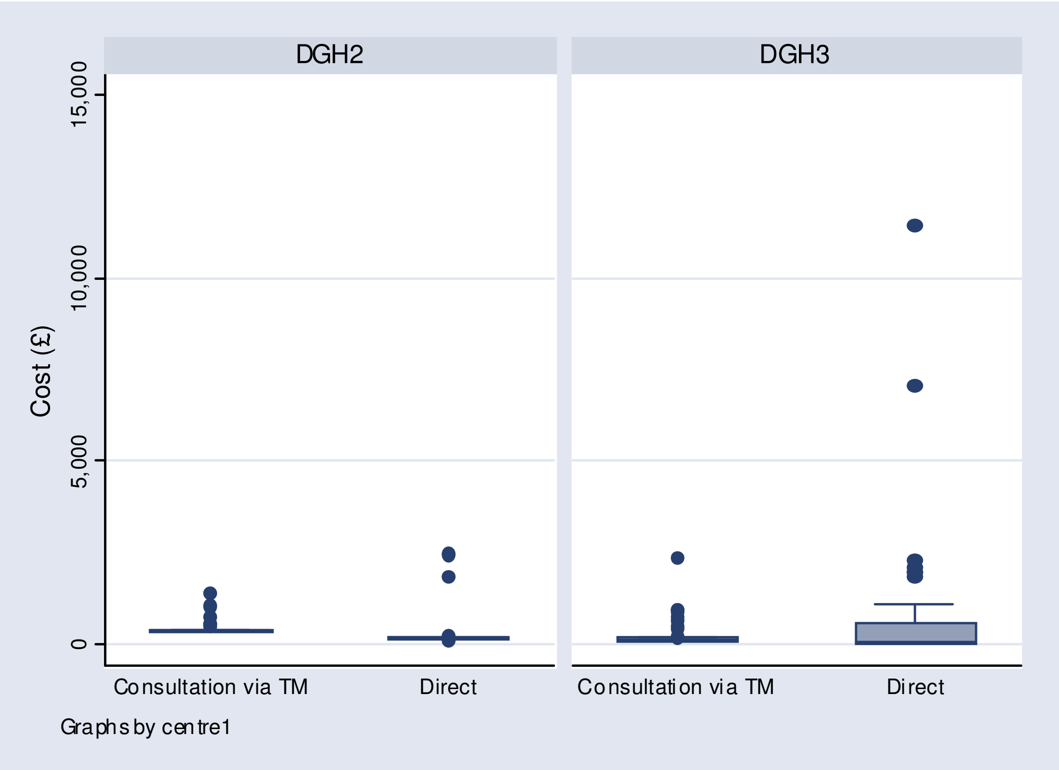


Figure E8: Cost per patient over 14 days (DGH2 n=38 telemedicine, 39 direct; DGH3 n=61 telemedicine, 32 direct)

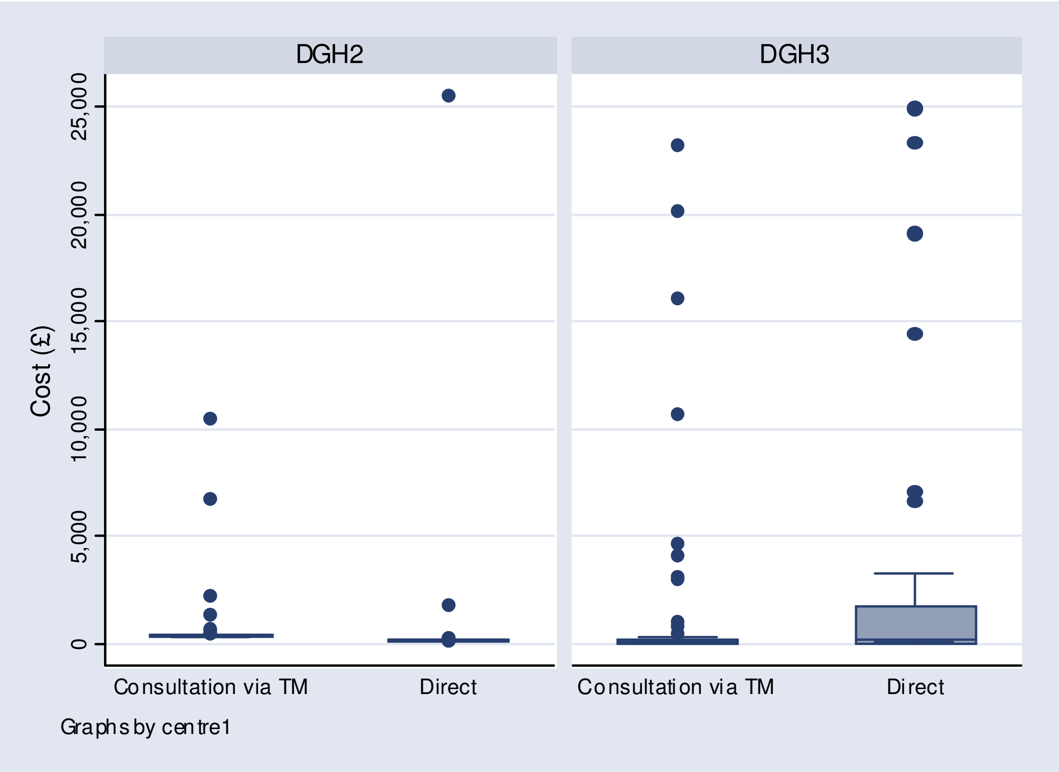
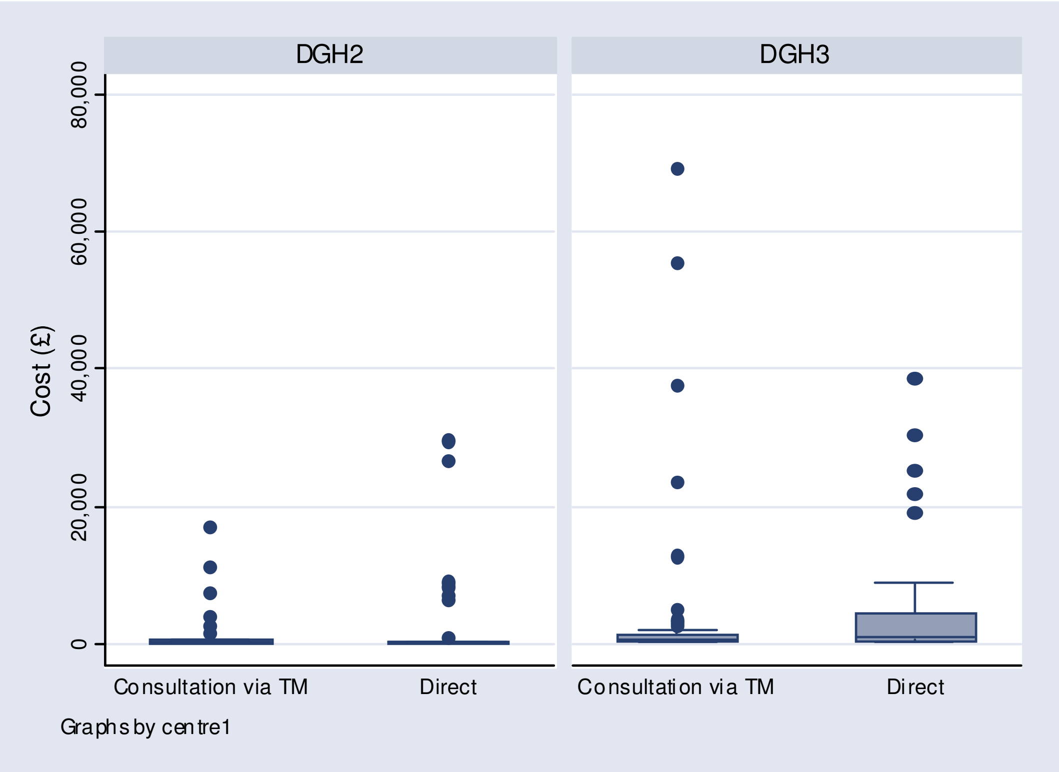


Figure E9: Cost per patient over six months (DGH2 n=38 telemedicine, 39 direct; DGH3 n=61 telemedicine, 32 direct)



APPENDIX F

TABLES AND BOX PLOTS FOR THE SENSITIVITY ANALYSES

APPENDIX F: TABLES AND BOX PLOTS FOR THE SENSITIVITY ANALYSES

A) NHS resource costs and women's travel costs

This sensitivity analysis took account of travel costs incurred by pregnant women who travelled directly to London for a fetal assessment or whose videoed ultrasound scan was transmitted remotely. The telemedicine women travelled to the district hospital. The sensitivity analysis was confined to women from DGH3, since this was the only hospital to use the telemedicine service for perinatal cardiology. Travel details were recorded in the questionnaires completed by the referred women, but as the postal survey was conducted over 10 months of the 15-month fieldwork phase, these details were not available for 57% of the referred women. Multiple imputation was used to estimate the missing costs.

Multiple imputation is a Monte Carlo simulation technique where each missing data case is replaced by a set of plausible estimates, and where the number of sets required is determined by the rate of missing information for the quantity being estimated. In this instance, 10 sets of estimates were required. The technique uses information on the relationship between variables as part of the estimation process. Information on the characteristics of the women, such as age, week of gestation, were included along with other items such as whether they were a telemedicine or a London referral, and mode of travel. Identical analyses were performed on each of the 10 sets. The results were combined using simple rules developed to produce overall mean estimates for the missing data.

The estimated travel costs for the women were added to their NHS resource costs for the initial consultation. Table F1 presents the bootstrapped mean cost per patient for the women's NHS resources alone, and their NHS resources and travel costs combined.

Table F1: Sensitivity analysis: Bootstrapped mean cost per woman in DGH3 for the initial consultation inclusive of personal travel costs

Initial consultation	Telemedicine	Direct to London	Total
NHS resource costs only			
Number Mean (SD) 95% CL	52 £143 (£10) £141 to £147	24 £63 (£14) £58 to £71	76 £117 (£40) £108 to £126
Sensitivity analysis (NHS resource costs plus travel cost)			
Number Mean (SD) 95% CL	52 £149 (£11) £146 to £152	24 £91 (£21) £83 to £101	76 £130 (£31) £123 to £137

NHS resource costs only: t test: $t = -27.21$, $p < 0.001$; Sensitivity analysis: t test: $t = -15.03$, $p < 0.001$

B) Shared use of the telemedicine service

During the years between finishing the fieldwork for the project and reporting its findings, the telemedicine equipment in DGH1 was used increasingly by the local cancer network for holding case conferences with clinicians in hospitals elsewhere in the County or in London. Paediatric telecardiology sessions were also held with the same frequency as during the 6-month service phase of the fieldwork. To assess the impact on the telemedicine service costs from this shared use, the itemised telephone invoice covering the first three months of 2005 was examined. During that period 15 cancer network sessions were held and approximately 10 patients were discussed per session. The total duration of the ISDN-6 linkups for the 15 sessions was 26.4 hours.

The assumptions for the sensitivity analysis were as follows:

- 300 cancer patients would be discussed over 6 months in addition to the 11 paediatric patients recorded during the 6-month service phase;
- The costs attributed to the telemedicine equipment, maintenance contract, ISDN-6 installation and training would remain the same;
- The 6-month telecommunication costs (including VAT) covering the ISDN-6 rental and linkups for the cancer networks and telecardiology sessions would be combined.

The total costs (bullet points 2 and 3 above) were shared among 311 users. The adjusted costs for the telemedicine components for DGH1 are included in Table F2.

Table F2: Sensitivity analysis - mean cost per patient for the components of the telemedicine service in the district hospitals (including the shared usage for DGH1)

Mean cost per telemedicine referral (£)	DGH1 (n=311)	DGH2 (n=38)	DGH3 (n=61)	DGH4 (n=7)
Telemedicine equipment	11.43	93.56	58.29	507.93
ISDN-6 line installation and maintenance contract	1.31	11.69	9.49	68.12
Telemedicine training costs	0.85‡	12.04†	8.00†	36.20‡
ISDN line rental and call charges	5.35‡	77.00†	55.90†	221.65‡
Total mean cost per referred patient	18.94	194.29	131.68	833.90

† Costs and charges pro rated over 12 months;
‡ Costs and charges pro rated over 6 months.

Table F3 presents the bootstrapped cost results for the DGH1 paediatric patients (infants and children) according to the shared usage assumptions. For comparison, Table F4 shows the results for the unadjusted telemedicine costs for this group of patients. The cost differences between the telemedicine and conventional referral strategies in the sensitivity analysis were not statistically significant for initial consultation and 14-day when compared with the baseline analysis.

Table F3: Sensitivity analysis for DGH1 (where the telemedicine costs have been shared by all users): bootstrapped mean cost per infant or child

Type of referral	Initial consultation	Fourteen days	Six months
Telemedicine			
Number	11	11	11
Mean (SD)	£240 (£204)	£1,590 (£4,686)	£1,641 (£4,670)
95% CL	£178 to £515	£178 to £7,929	£217 to £7,932
Conventional			
Number	48	48	48
Mean (SD)	£268 (£709)	£274 (£730)	£853 (£2,034)
95% CL	£163 to £712	£165 to £731	£456 to £1,798
Test results (t test)	t = 0.12, p = 0.901	t = -1.90, p = 0.062	t = -0.88, p = 0.385

Table F4: Bootstrapped mean cost per infant or child in DGH1 when the telemedicine costs are shared only by the cardiac patients

Type of referral	Initial consultation	Fourteen days	Six months
Telemedicine			
Number	11	11	11
Mean (SD)	£740 (£204)	£2,089 (£4,686)	£2,140 (£4,670)
95% CL	£677 to £1,015	£677 to £8,429	£720 to £8,431
Conventional			
Number	48	48	48
Mean (SD)	£268 (£709)	£274 (£730)	£853 (£2,034)
95% CL	£163 to £712	£165 to £731	£456 to £1,798
Test results (t test)	t = -2.17, p = 0.034	t = -2.63, p = 0.011	t = -1.43, p = 0.157

Note: The statistical tests were conducted on non-bootstrapped mean costs.

APPENDIX G

PREDICTING TELEMEDICINE USAGE ACROSS ALL PATIENT GROUPS IN THE FOUR DISTRICT HOSPITALS

APPENDIX G: PREDICTING TELEMEDICINE USAGE ACROSS ALL PATIENT GROUPS IN THE FOUR DISTRICT HOSPITALS

Authors: Hema Mistry and Tracey Young

Modelling was undertaken to determine whether the results from the analyses of the telemedicine usage for each group of patients could be generalised to district hospitals elsewhere. Logistic regression models were fitted to the observed caseloads for each patient group separately in the hospitals that used the telemedicine service. These models were then used to identify variables that were good predictors of the referral method selection. Next, for each patient group, the variables were entered in a multivariate logistic regression model in order to predict the overall size of the telemedicine caseload. Finally, the models were fitted to the observed caseloads in each hospital to measure their predictive accuracy.

1. Demographic characteristics of patients referred to specialists

Table G1 shows the characteristics of the referred patients according to the referral methods. For the women, there were statistically significant differences in maternal age, type of pregnancy, fetal risk status, and gestation at the time of the anomaly scan. For the newborn babies, there was no statistically significant difference in any demographic characteristic. As for the older children, there was no statistically significant difference in age or gender. However, there was a statistical significant difference in timing (i.e. whether the referral was made before the hospital began using the telemedicine service or afterwards), and the assessment of severity approached a level of significance.

Table G1: Demographic characteristics of the patients referred to specialists

Characteristics	Referral method		Test result
	Telemedicine	Direct	
Pregnant women	**N = 52**	**N = 196**	
Mean age (SD)	28.7 (6.1)	32.1 (6.0)	t = 3.66, p < 0.001
Parity Primaparous Multiparous	 19 (36.5%) 33 (64.5%)	 52 (26.5%) 144 (73.5%)	χ_1^2 = 2.01, p = 0.156
Type of pregnancy Singleton Multifetal	 52 (100.0%) 0	 168 (85.7%) 28 (14.3%)	χ_1^2 = 8.37, p = 0.004
Fetal risk status Cardiac anomaly Down's syndrome Low risk	 41 (78.8%) 5 (9.6%) 6 (11.5%)	 80 (40.8%) 57 (29.1%) 59 (30.1%)	χ_2^2 = 23.81, p < 0.001
Gestation at anomaly scan ≤18 weeks 19 – 21 weeks ≥ 22 weeks	 2 (3.8%) 42 (80.8%) 8 (15.4%)	 39 (19.9%) 107 (54.6%) 50 (25.5%)	χ_2^2 = 12.89, p = 0.002
Newborn babies	**N = 17**	**N = 23**	
Mean age in days (SD)	12.7 (24.5)	9.5 (13.4)	t = -0.53, p = 0.601
Mean birthweight (SD)	2.5 (1.1)	2.8 (1.1)	t = 0.89, p = 0.380
Gender Male Female	 10 (58.8%) 7 (41.2%)	 14 (60.9%) 9 (39.1%)	χ_1^2 = 0.17, p = 0.896
Referral timing Prompt referral Delayed referral	 13 (76.5%) 4 (23.5%)	 14 (60.9%) 9 (39.1%)	χ_1^2 = 1.08, p = 0.298
Urgency of symptom** Less urgent Urgent	 15 (88.2%) 2 (11.8%)	 15 (65.2%) 8 (34.8%)	χ_1^2 = 2.76, p = 0.097
Older children	**N = 48**	**N = 168**	
Mean age (SD)	4.4 (5.2)	5.1 (4.5)	t = 0.82, p = 0.415
Gender Male Female	 26 (54.2%) 22 (45.8%)	 92 (54.8%) 76 (45.2%)	χ_1^2 = 0.01, p = 0.942
Severity Normal/Mild Moderate/Severe	 44 (91.7%) 4 (8.3%)	 134 (79.8%) 34 (20.2%)	χ_1^2 = 3.65, p = 0.056
Timing of the referral Pre-telemedicine uptake Post-telemedicine uptake	 0 48 (100.0%)	 35 (20.8%) 133 (79.2%)	χ_1^2 = 11.93, p = 0.001

Definitions (from the Third Report on neonatal cardiology services):

- Referral timing: Prompt – within 72 hours of birth or readmission; Delayed – after 72 hours.
- Urgency of symptoms: Less urgent – non critical congenital heart disease suspected; Urgent – critical congenital heart disease suspected.

2. Determining predictive factors

Logistic regression models were fitted individually to the demographic characteristics for each patient group in those hospitals that used the telemedicine service. This was done to determine which factors, if any, were significant predictors whether a patient was assessed via telemedicine or direct referral (Table G2).

For the women, fetal risk status was the only statistically significant predictor – women with a high risk for a fetal cardiac anomaly were more likely to seen by telemedicine. For the newborn babies, urgency was the only statistically significant predictor – less urgent cases were more likely to be seen via telemedicine. Finally, for the older children, district hospital and timing were statistically significant predictors of referral mode.

Table G2: Logistic regression models fitted individually to the demographic characteristics for each patient group to predict referral mode

Demographic characteristics	Regression coefficient	Standard error	z statistic	p-value
Pregnant women				
Age	-0.023	0.040	-0.59	0.555
Parity: prima	-0.552	0.500	-1.11	0.269
Parity: multi	Base*			
Risk: cardiac anomaly	Base*			
Risk: Down's syndrome	-1.652	0.677	-2.44	0.015
Risk: low	-1.316	0.670	-1.96	0.049
Gestation – 21#	-0.45	0.287	-1.57	0.117
Newborn babies				
Age (days old)	0.002	0.018	0.12	0.905
Gender: male	Base*			
Gender: female	0.432	0.731	0.59	0.555
Birthweight	-0.204	0.329	-0.62	0.535
Referral: prompt	Base*			
Referral: delayed	-0.927	0.762	-1.22	0.224
Urgency: less	Base*			
Urgency: urgent	-1.764*	0.906	-1.95	0.052
DGH2	2.197	1.155	1.90	0.057
DGH3	1.216	0.950	1.28	0.200
DGH4	Base*			
Older children				
Age	-0.008	0.038	-0.22	0.826
Gender: male	Base*			
Gender: female	-0.026	0.345	-0.08	0.939
Severity: normal/mild	Base*			
Severity: moderate/severe	-0.664	0.531	-1.25	0.211
Timing: pre-TM uptake	Base*			
Timing: post-TM uptake	4.664	1.031	4.52	< 0.001
DGH1	-1.328	0.412	-3.22	0.001
DGH2	Base*			
DGH4	-1.613	0.541	-2.98	0.003

* Base case scenario #Standardised to the most frequent gestation week for model cohort

3. Identifying cases for telemedicine

In order to identify the patients predicted to be seen via telemedicine, a multivariate logistic regression model was fitted to the data for each group. All variables listed in Table G1 were included in the model and the least significant variables were removed one at a time, using a forward stepwise regression model, until only those variables with a significance level < 0.1 remained in the model (see Table G3 below).

Table G3: Multivariate logistic regression models fitted to demographic characteristics for each patient group individually in order to predict referral mode

Predictors of referral mode	Regression coefficient	Standard error	t statistic	p-value
Pregnant women				
Risk: cardiac anomaly Risk: Down's syndrome Risk: low	Base* -1.847 -1.303	 0.730 0.680	 -2.53 -1.92	 0.011 0.055
Gestation – 21#	-0.505	0.296	-1.71	0.088
Constant term	1.303	0.344	3.78	< 0.001
Newborn babies				
DGH2 DGH3 DGH4	2.404 1.971 Base*	1.219 1.067	1.97 1.85	0.049 0.065
Urgency: less Urgency: urgent	Base* -2.211	 1.009	 -2.19	 0.028
Constant term	-0.945	0.831	-1.14	0.255
Older children				
DGH1 DGH2 DGH4	1.116 Base* -0.212	0.700 0.673	1.59 -0.32	0.111 0.753
Timing: pre-TM uptake Timing: post-TM uptake	Base* 5.285	 1.146	 4.61	 < 0.001
Constant	-5.119	1.171	-4.37	< 0.001

* Base case scenario # Standardised to the most frequent gestation week for model cohort

4. Predicting telemedicine caseloads

The logistic regression models presented in Table 3 were applied to each patient group in order to obtain a regression prediction score. Patients with a prediction score of less than 0.5 were set to 0 – direct referral, whilst patients with scores greater than 0.5 were set to 1 – telemedicine. To illustrate, with reference to Table G3, consider the following three examples:

A) A pregnant women with Down's syndrome risk scanned at 18 weeks:

Women A = 1.303 –1.847 – (0.505*(18-21)#) = 0.97 [i.e. Telemedicine]

B) A newborn baby referred from DGH4 who was an urgent case:

Newborn baby B = -0.945 – 2.211 = 3.16 [i.e. Direct]

C) An older child who was seen in DGH2 post-TM uptake:

Older child C = -5.119 + 5.285 = 0.17 [i.e. Direct]

Patients B and C have scores less than 0.5 and so they would have been referred directly, whereas patient A has a score greater than 0.5 and therefore was predicted to have been a telemedicine case.

5. Model of goodness of fit

The three multivariate logistic regression models from Table G3 were fitted to the observed caseloads for each patient group in order to measure their predictive accuracy.

For pregnant women:

- The log likelihood for multivariate logistic regression model for women was –41.69, this was statistically significant, indicating a well fitting model (χ^2_3 = 11.42, p = 0.010).
- Of the 196 women who were actually referred directly to London, the model predicted that 70 (35.7%) would be referred using this method;
- Of the 52 women who were actually seen by telemedicine, the model predicted that 42 (80.8%) would be referred using this method.

For newborn babies:

- The log likelihood for multivariate logistic regression model for newborns women was –17.92, this was statistically significant, indicating a well fitting model (χ^2_3 = 9.88, p = 0.020).
- Of the 23 newborns who were actually referred directly, the model predicted that 19 (82.6%) would be referred using this method;
- Of the 17 newborns who were actually seen by telemedicine, the model predicted that 13 (76.5%) would be referred using this method.

For older children:

- The log likelihood for multivariate logistic regression model for older children was -59.66, this was statistically significant, indicating a well fitting model (χ^2_3 = 77.58, p < 0.001).
- Of the 168 older children who were actually referred directly, the model predicted that 138 (82.1%) would be referred using this method;
- Of the 48 older children who were actually seen by telemedicine, the model predicted that 42 (87.5%) would be referred using this method.

For all patients groups:

- The overall predictive accuracy of the three models was 64.3%.
- 97 (82.9%) of the 117 actual telemedicine referrals were predicted as telemedicine cases.
- 227 (58.7%) of the 387 actual direct referrals were predicted as directly referred cases.

These numbers are set out in Table G4 and the shading in the cells indicates specialist consultations that were actually conducted using the referral mode predicted by the model.

Table G4: Comparison between the actual modes of referral and the referral modes predicted from the multivariate logistic regression referral models

	Predicted direct referral	Predicted teleconsultation	Total actual referrals according to mode
Pregnant women			
Actual direct referral	70	126	196
Actual teleconsultation	10	42	52
Newborn babies			
Actual direct referral	19	4	23
Actual teleconsultation	4	13	17
Older children			
Actual direct referral	138	30	168
Actual teleconsultation	6	42	48
Total predicted referrals according to mode	247	257	504

6. Summary

Modelling was undertaken to determine whether the results from the analyses of the telemedicine usage could be generalised to all services in the district hospitals elsewhere. Logistic regression models were fitted individually to each patient group for those patients who used the telemedicine service and the statistically significant characteristics were used to predict the telemedicine caseloads. The overall predictive accuracy of the three models combined was 64% (97 of the 117 actual telemedicine referrals were predicted as telemedicine cases; and 227 of the 387 actual direct referrals were predicted to use this method).

Appendix G: Predicting telemedicine usage across all patient groups in the four district hospitals

APPENDIX H

COST ANALYSES OF THE MODELLED TELEMEDICINE SERVICES

APPENDIX H: COST ANALYSES OF THE MODELLED TELEMEDICINE SERVICES

Author: Hema Mistry

1. Applying costs to the results obtained from the logistic regression models

Before cost analyses could be performed based on the results obtain from the logistic regression models in Appendix G, adjustments had to be made to the observed costs for the three patient groups in each district hospital according to the predicted method of referral. For this appendix, we are concentrating on the initial consultation.

a) Cost adjustment for the three patient groups according to the model predictions

- For pregnant women who had visited London, the cost of a specialist scan plus time of a consultant was replaced by the cost of a teleconsultation, or vice versa.
- For the newborns who were transferred to London, the cost of the transfer and time spent as an inpatient in the London hospital for that day was replaced by the cost of teleconsultation and bed day cost in the local hospital, or vice versa. The cost of a specialist echocardiogram was replaced by the cost for a DGH echocardiogram, or vice versa.
- For the older children who were seen in the outreach clinics, the cost of the clinic attendance plus staff time was replaced by the cost of a teleconsultation, or vice versa. The cost of an outreach echocardiogram was replaced by the cost of a telemedicine echo, or vice versa.

b) Telemedicine service costs

The teleconsultation cost for each of the three patient groups covered the telemedicine equipment, training costs, ISDN-6 line installation, telephone bills, and the telemedicine consultation itself (i.e. staff time). The mean equipment / installation cost per patient, mean quarterly telephone bills per patient and the mean training cost per patient for each hospital were divided by the number of predicted teleconsultations in each hospital. For each patient group, a mean time for a teleconsultation which included the specialist's time, the district hospital clinician's time and the telemedicine coordinator's time was calculated from the observed teleconsultations.

Once the costs for each patient were adjusted, bootstrapping was applied to obtain a mean cost per patient.

2. Cost results from the logistic regression models

Table H1 shows that for the initial consultation, the mean cost for referred patients who were seen via a telemedicine link up is lower than the mean cost for patients referred directly to London. The cost difference of £198 was statistically significant (p=0.003). However, there was a marked inter-group variation in the pattern of the mean costs. If women saw a specialist only once during their pregnancy, it was cheaper to send them directly to London rather than hold a teleconsultation; the cost difference was statistically significant (p<0.001). For newborns, the mean cost of seeing a specialist via the telemedicine link in their local hospital was cheaper than transferring them to a specialist unit in London. Most of the mean cost for a transferred baby was accounted by the ambulance transfer (£1,476) and occupancy of a specialist cot (£1,020 per day). For the older children, there was only a little difference in the mean costs (£37) between an outreach clinic attendance and a teleconsultation.

Table H1: Bootstrapped mean cost per patient for the predicted telemedicine and predicted direct referrals for the initial consultation

	Telemedicine	Direct referral	t test result
All referred patients			
Number Mean (SD) 95% CL	257 £195 (£166) £177 to £217	247 £393 (£1,076) £288 to £566	t = 2.94, p = 0.003
Pregnant women			
Number Mean (SD) 95% CL	168 £109 (£47) £103 to £117	80 £60 (£12) £58 to £64	t = -6.39, p < 0.001
Newborns			
Number Mean (SD) 95% CL	17 £648 (£297) £514 to £800	23 £2,453 (£2,353) £1,782 to £4,040	t = 1.90, p = 0.065
Older children			
Number Mean (SD) 95% CL	72 £287 (£54) £276 to £301	144 £250 (£591) £180 to £406	t = -0.54, p = 0.592

Note: Statistical tests were performed on non-bootstrapped mean costs.

APPENDIX I

CONFERENCE ABSTRACT: APPLICATION OF PROPENSITY SCORE MATCHING

APPENDIX I: CONFERENCE ABSTRACT: APPLICATION OF PROPENSITY SCORE MATCHING

Poster: International Society for Pharmacoeconomics and Outcomes Research (ISPOR) 7th Annual European Congress, 24-26 October 2004, Hamburg, Germany.

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OBJECTIVES: Propensity score matching (PSM) is a method used to address selection bias in observational studies and to date has been used mainly in survival analysis. This study has used PSM when determining antenatal costs for alternative referral modes (via telemedicine (TM) or direct referral) for obtaining specialist advice for pregnant women at risk of a fetal cardiac anomaly.

METHODS: Three district hospitals (DH) in south-east England were offered the use of a fetal cardiology telemedicine service. Two hospitals (DH1 and DH3) continued to refer all patients directly to London, while the third hospital (DH4) used both referral modes. A logistic regression model was fitted to women in DH4 in order to predict what proportions of women in DH1 and DH3 would have been seen via TM, had that service been taken up. PSM was then used to match `TM' cases to `direct referral' cases. A total cost per woman was obtained for all antenatal resource use incurred during the study and the costs were adjusted for those predicted as TM cases. Finally, the costs for the predicted modes and matched modes were compared.

RESULTS: The logistic regression model predicted 153 women be assessed via TM and the remainder (n=84) as direct referrals. Mean antenatal cost per patient for the TM group was slightly higher (£606), although not significantly so, compared with the direct referral group (£561). After applying PSM, 66 TM cases were matched to 55 direct cases. The magnitudes of the PSM costs (TM group, £671, and direct group, £551) were similar to the logistic regression model. Comparisons of cost results by referral mode and analytical method were not statistically significant.

CONCLUSIONS: PSM indicated that the cost results from the logistic regression model were reliable. We conclude that there is a role for PSM in economic evaluation.

APPENDIX J

CONFERENCE ABSTRACT: PARENTAL SATISFACTION WITH MODE OF DELIVERY OF SPECIALIST ADVICE

APPENDIX J: CONFERENCE ABSTRACT: PARENTAL SATISFACTION WITH MODE OF DELIVERY OF SPECIALIST ADVICE

Oral presentation: Telemed and eHealth '05, London 28-29 November 2005

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INTRODUCTION: This paper reports on one component of the TelePaed study, which is investigating the cost-effectiveness of telemedicine for the provision of specialist paediatric cardiology advice to district general hospitals DGHs.

Previous reports of satisfaction with telemedicine services have rarely compared the new telemedicine service with the conventional service it would replace or complement. (Mair and Whitten, 2000). In the Telepaed study prospective data were collected for both telemedicine and conventional services.

METHODOLOGY: Four DGHs which were already referring patients to a London tertiary centre were randomised to continue with the established service provision or to use telemedicine via ISDN-6 technology.

The patients in this part of the study were babies, toddlers and children for whom an urgent cardiac opinion was required and other newly referred patients who would otherwise have been seen by a specialist in their routinely scheduled outreach clinics.

After the consultation with the specialist heart doctor, which was held either via telemedicine or in a clinic, the parents of patients were sent a postal questionnaire which contained 11 statements relating to the consultation. There were 10 additional statements applying only to consultations that took place via the telemedicine link.

Respondents rated each satisfaction statement according to five levels of agreement. The statements were analysed individually rather than being grouped into scales or domains. The sub-group analysis compared levels of satisfaction with telemedicine consultations versus clinic consultations, using Fisher's exact test and Chi square to test for significant differences

.

RESULTS: The satisfaction statements were rated by parents in 100 questionnaires relating to:

- 20 who experienced telemedicine
- 56 new children seen in the outreach clinics
- 24 children on review whose next appointment was at the specialist centre.

The parents' personal views were consistently much more positive than negative for both consultation modes. In particular, few parents were embarrassed speaking to the specialist, even across the telemedicine link.

Unanimity of opinion between the two groups of respondents was generally lower for the statements on the consultation process. Telemedicine parents agreed significantly more often than clinic parents that they had received an explanation about how the advice from the specialist would be obtained (p=0.022) and they agreed overwhelmingly that the pictures, which were being considered, could be seen clearly (p=0.003).

High levels of unanimity in the parents' assessments with respect to the practicality of telemedicine services and the technology itself were demonstrated believing that

- teleconsultations could save them travelling time and money
- the technical aspects of sound and picture quality were acceptable
- they were not discomforted by the technology and felt reassured by the consultation with the specialist.

There was more ambivalence towards the statements suggesting that teleconsultations take the place of conventional face-to-face consultations.

CONCLUSION: The majority of parents were satisfied with the service they were receiving, though the satisfaction in terms of explanatory advice and quality of pictures was significantly higher for those involved with the telemedicine link. Parents of children seen via the telemedicine link were, generally, satisfied with the technology and the service.

Appendix J: Conference abstract: Parental satisfaction with mode of delivery of specialist advice

APPENDIX K

DISCUSSION GROUPS HELD IN THE DISTRICT HOSPITALS AT THE END OF THE PROJECT'S FIELDWORK

APPENDIX K: DISCUSSION GROUPS HELD IN THE DISTRICT HOSPITALS AT THE END OF THE PROJECT'S FIELDWORK

Author: Gwyn Weatherburn

At the end of 2002, after the completion of the data collection for the project, group discussions were held in each of the district hospitals to obtain the views of hospital staff about the telemedicine in the hospital. Key staff in the Directorates of Paediatrics and Obstetrics were invited to attend lunch time sessions which were coordinated by two researchers from the project team. Each session lasted for about an hour. The discussions were recorded on audio tape and transcribed.[#]

Key points which emerged were:

- The four hospitals chose to use the telemedicine facilities for different applications within the two directorates.
- Learning to use the telemedicine technology was less problematic and time consuming than learning/updating skills for ultrasound examinations to demonstrate cardiac anatomy and blood flow.
- Since cardiac diagnoses and patient management decisions are dependent upon the viewing of ultrasound images, the location of the telemedicine equipment in relation to the location of the ultrasound or echocardiography machines is crucial. As one obstetrician stated

  > *'But the important thing, …the [telemedicine] equipment is in the room where we do the scan. Anything in the main part [of the hospital] is like a trip out to Siberia, in that you don't do it very often'.*

- Transmitting live scans in a small neonatal unit can be a potential risk to all babies in the unit if bulky telemedicine equipment has to be taken into the unit.
- There must be mutual trust and professional respect between the staff in the specialist hospital and the staff in the district hospital: collaborations are more successful when staff have already worked together before telemedicine is introduced.

  > *'You want to have somebody like [the regular cardiologist] who's very sound and used to us. Because we have had other cardiologists. It's not the same… We had to bring the patients back on both occasions…, or re-present them at a later stage. The level of confidence they have with you …'*

- Co-ordination is essential at 'both ends' of the telemedicine system and this is particularly important out of normal working hours when urgent advice is required. There should always be someone available in the specialist hospital who is able to use the technology and has the expertise to provide specialist advice.
- Access to the telemedicine technology usually was not widely offered to other directorates within the hospitals
- The on going costs (i.e. ISDN-6 charges) and possible maintenance of the technology from already tight budgets was a concern for budget holders.

[#] We thank Avril Cook for transcribing the audio tapes.

- The electronic stethoscope was not used as often as was expected at the start of the project.
- There were some teething problems when the telemedicine technology was first used. Some problems were related to linking the equipment with a suitable echocardiography machine
- Clinicians who had experienced telemedicine sessions were generally supportive of this method of obtaining specialist advice.

A selection of comments are reported under 12 sections:

1. Views of the telemedicine technology
2. Location of telemedicine equipment
3. Equipment to support the telemedicine service
4. Technical problems
5. Training issues
6. Ultrasound and echocardiography scans for telemedicine transmission
7. The telemedicine service complementing existing outreach clinic services
8. Urgent requests for advice
9. Importance of personal relationships between hospital staff and specialists
10. Co-ordination of telemedicine
11. Costs of the telemedicine service borne by the district hospitals
12. Educational benefits of the telemedicine service

Within each section the comments from the two Intervention hospitals are given first, (i.e. DGH2 and DGH3), followed by those from the control hospitals DGH1 and DGH4. This order is used throughout and bears no significance to whether or not the comments relating to telemedicine were favourable. Speakers have been anonymised and are indicated by their specialty, the district hospital code, and personal code (e.g. A, B or C). The various Royal Brompton [The Brompton] paediatric cardiologists who participated in the teleconsultations and conducted the outreach clinic are simply referred to as 'the specialist'.

Some lengthy sections of discussions are given in order to provide the context in which comments were made. Some duplication of comments will be noted where comments are relevant to more than one section.

It is worth noting that the intervention hospitals knew a year in advance that they were randomised to use the telemedicine service from mid-2001, whereas the control hospitals were offered the opportunity to use the service for the purposes of the project at short notice and neither hospital was in a position to start using the service immediately.

1. Views of the telemedicine technology

Intervention hospitals
DGH2

Paediatrician 2A. The clinicians like it …it's very good access to a specialist centre and the mothers like it… It's less travelling. But to make this project viable we have to use it more. We have to see more numbers. That means we need to have people willing to do it at this end and provide the other side, to make the service more financially viable. Because if you are in a remote place like Australia it makes sense to have telemedicine which is due to the distance factor. Here we are very well provided with transport links to and from the Cardiac Centres…. So in that sense having telemedicine is a bit of a luxury.

DGH3

Obstetrician 3A: You'll have to face up to Sonographer 3A and the rest if you try and nick it [telemedicine equipment].

Control hospitals
DGH1

Paediatrician 1A: …I thought it [telemedicine] was very useful actually, it was a lot easier than I thought it was going to be. I was completely sceptical beforehand and wondered how interactive it would be and whether I'd feel a bit silly sitting there discussing [cases]. But in fact I think it was useful, because a lot more discussion can go on, about the echo,.... lots of different things, like the technique …so that was very useful. I think it's really just the time.

Researcher 1: So you're going to continue?

Paediatrician 1A: Yes certainly…I mean, I think discussion always works not just the diagnostic process, I think parents quite like the idea, if you have a particularly difficult child to echo and you're not sure if it's mildly [abnormal] ...just not a 100% sure and the parents are particularly anxious ... lots of different options,…By the time they come to have an echo, it's very useful to the parents to say well actually I think this is fine, but… I'll show it to the telemedicine link and I'll write to you and I'll confirm later the findings and bring the child back in a year's time. They seem to quite like that way, that additional assurance.

DGH4

Paediatrician 4B: It would be a shame actually to be too negative. If we had the machine [ultrasound] earlier on with the Telemedicine link, I think if you do the same study now [Dec 2002], things will be different. …It's only in the last 3 months actually, that we have been fully operational…If you did the same study now I'm sure you will get an entirely different picture which is a very much more positive picture… Particularly in the post natal or at least in the older children who have had surgery, who needs exclusion of diagnosis who need sort of immediate treatment or whatever. So in a way things have moved on from the time we finished the study.

Researcher 2: And how about the parents of the patients? Are they usually present?

Paediatrician 4A: Yes. I think that they love it, because [the specialist] talks to them in front and they're just face to face discussions and really everybody gets very happy, very happy....The children love it.

Paediatrician 4B: …What I found is the parents don't seem to ask so many questions.

Paediatrician 4A He [the specialist] has to prompt most of the questions.

Researcher 2: So they're slightly more inhibited, yes?

Paediatrician 4B: Whereas face to face they tend to ask lots of questions. … It's an impression. I don't know whether it's actually true or not.

Researcher 1: You've got two televisions haven't you? …. Do they see themselves on one?

Paediatrician 4B: Yes.

Researcher 1: Do you think that is inhibitive?

Paediatrician 4B: Well last week, that wasn't working so it was OK. But previously, yes.

2. Location of telemedicine equipment

The telemedicine equipment packages were designed to give the hospitals flexibility in holding teleconsultations in different settings according to the physical layout of the neonatal, paediatric and obstetric accommodation. There was an element of trial and error in working out the optimal positioning of the equipment (i.e. the trolley fitted with the camera and other items, and the twin monitors - see Appendix B) and the outlets for the ISDN-6 lines.

Intervention hospitals

DGH2: In this hospital there were concerns about taking the telemedicine equipment into a small neonatal unit for teleconsultations.

Sister Baby Unit 2: I mean, the only thing I'll say about the Telemedicine equipment, I much prefer the video [method]…We had it once on the Unit [for a live transmission] and I felt that it was just too much equipment and it put other babies at risk because it was just a nightmare…We had to move the baby who was already very unstable into an HDU that was already full up with other babies and the equipment is just a nightmare and unsafe to have if it's fairly full ITU or HDU to have all that equipment and people, it's just too much. Much, much more beneficial to have the video and then do the echo in fairly safe surroundings and then take it up.

Manager: Now we've moved [the Unit] it might be easier, but if you're full it's still going to be a problem.

Paediatrician 2A I mean the principle's all right, it's just the logistics of actually, the fact that we have a very small cramped and crowded Baby care unit… It's very good, a very useful thing to have.

Paediatrician 2B But it is better to sometimes …do a live echo, the reason being the cardiologist at the other end might want something different and want it shown. With a video you can't, so that means coming and scanning the baby. But things are a bit better. At that time we were in cramped accommodation, now we have moved out of that.

This hospital had also installed telemedicine facilities in the postgraduate centre.

Researcher 1: Would you be happy to use the equipment, which has been put in the Post Graduate Centre?

Paediatrician 2A: … I'd have to think about it.....The main attraction as I say is doing the live scan, having somebody over my shoulder telling me what to do and what to look for but that's the only thing that you can't do up there, because you can't take an ultrasound machine up there..... up the other end of the hospital, but everything else could live up there and we could hold our clinics up there. In that respect I can't imagine any problem on Friday afternoons.

DGH3: This intervention hospital used the telemedicine service for babies in the neonatal unit and for screening obstetric patients for fetal cardiac abnormalities.

> *Paediatrician 3A: … Obviously the bulk of our echos [for neonates] are recorded and then transmitted, although we have done real-time and we've had no difficulty in doing that if they're in the treatment room… On the Neonatal Unit there is a physical distance from where the point is to the nearest cot, so the baby has to be close to the ISDN points and we've made sure that those babies are put there… the cot has to be moved to the nearer point, but it can be done, we've done it. So it's not a major issue, we have the capability of transmitting from Intensive Care, we've done that, twice or three times I think... One of the things is we didn't set up separate lines in all the areas. We've just got two links and we've got feeder lines coming off them and that would be a very cheap way of doing it for other departments.*

Control hospitals

DGH1: Location was a major issue in this control hospital in which clinical services were in several separate buildings linked by corridors. The siting of the telemedicine equipment in a central suite in a different block contributed to the lack of its use for fetal medicine.

> *Obstetrician 1A. … The first thing, it [the equipment] has to be at a convenient place in relation to where you do the work… So if you have to make a long detour to use it then the chances of using it go down. In fact we've only used it once, directly…we were promised a lump sum [not from project]. This would allow us to do two things, one move the machine into the room where we wanted it …So we look forward to having the equipment in the room where we do the scans so that we could have a fixed day where we would be able to do the scan and get through to whoever we wanted to for a direct look, which is the only real hard-line benefit we would see because then you can have a two-way rather than I video something and then a week later they'll go and play it back. So we're looking forward to that…*
> *Paediatrician 1B I think it would be useful to have it [teleconference equipment] somewhere near special care, so you can walk your older children there, whereas with a sick neonate you don't want to move them there.*

DGH4: The paediatricians in this control hospital scanned the sick babies in the neonatal unit using a new echocardiography machine with an inbuilt recorder, and they took the machine to the telemedicine equipment in the paediatric ward on the floor below for transmission.

> *Paediatrician 4B: We do a live scan .... Mainly we do the live scans, on two occasions because the baby was sick. So I couldn't transfer that day, so I recorded it on the Unit and then I had to take the scanner down stairs and talk to the [specialist].*

3. Equipment to support the telemedicine service

a) Electronic stethoscope and object camera provided by the project

Intervention hospitals

DGH2

> *Paediatrician 2B: <u>The stethoscope</u>. We have used it on a few occasions. It hasn't been used that regularly. The reason being that sometimes the other end is not ready or we haven't got it working for a while. There were some practical difficulties.*

Researcher 2: And you use the object camera?

> *Paediatrician 2B: Yes. It shows the areas you're interested in. … It's like a normal [outreach] consultation….*

DGH3

> *Paediatrician 3A The electronic stethoscope, we've been a little bit slow with that, because there were some technical problems with it and now that we've got it working, we tested it two weeks ago and again that works fine…*
>
> *We actually have used the [object camera] plate to actually transmit an ECG… and that was quite useful.*

Researcher 1: Was that a paper tracing?

> *Paediatrician 3A: Paper tracing. Chest X-rays we've done, and those actually transmit very well, so there's no doubt that those two things were very helpful, if and when we want to do it.*

Control hospitals

DGH1: There was an unforeseen delay in supplying this control hospital with an object camera.

Researcher 2: Have you used the electronic stethoscope?

> *Paediatrician 1A: No I haven't yet…but I think it would be quite interesting to use, but it's really just the logistics, of having young children…it's fine if you have 10 year olds, but even a few of the toddlers you couldn't manage if you wanted to do that.*
>
> *Certainly the [showing] of the X-rays and ECGs [using an object camera] would be very helpful, I mean, I think from a personal view, I'd find that more helpful than electronic stethoscope... Hopefully there is one [object camera] coming. That would be useful.*

DGH4

Researcher 1: Now you've got the electronic stethoscope, have you found it useful?

> *Paediatrician 4A: We use it only in certain cases. Right, if we are not sure, hear a murmur and we can't find any abnormalities then we do use it. Only 50% of occasions, not in 100%.*

Researcher 1: And those 50% that you do use it, do you think it's essential? If you didn't have the electronic stethoscope would you have to send the child to The Brompton?

> *Paediatrician 4A: I don't think so. I think it aids your diagnoses only*

Researcher 1: You have had some urgent newborns. Is the stethoscope more important with those?

> *Paediatrician 4C: We did urgent ones before we got the stethoscope. We just described our findings.*

Researcher 2: Do you use the object camera?

> *Paediatrician 4A: We haven't tried it yet.*

b) Obstetric ultrasound video equipment

DGH3: Although a video machine was installed on the telemedicine equipment trolley, it was not used for recording obstetric ultrasound images for future transmission, because the trolley was kept on a different floor of the hospital. Instead, an additional video recorder was acquired.

Sonographer 3A: When it [the telemedicine service] first started I didn't quite know how it was going to affect the day to day working system…We do routine anomaly scans at 21 weeks. We would check the heart, but for this purpose obviously we had to do the extra views. So when we first set this [service] up we brought people back at around 23 weeks just to do the heart and we came across a couple of problems. Firstly that there wasn't a video on the actual scan machine so that was a major problem because we didn't know how to sort of transmit it… We had to come up to Special Care and scan the first three patients on the echo machine up there that had a video. But then for future occasions we had an old video lying about in an old machine which we had to take off.
…So now, when we want to do a Telemed scan, we don't book them [the women] as an extra to our list. We just do the scan as we would a routine normal scan but just take them into the room with the video, just video it and off they go [home]. It's a lot easier, it doesn't really cause a lot of upheaval.

4. Technical problems

Intervention hospitals

DGH2: There was one occasion when the link up for a teleconsultation session failed to work satisfactorily, causing embarrassment to all concerned.

Paediatrician 2A: We got through to [The Brompton]. What actually happened was everything seemed to work except for the picture ... to a degree and then it disappeared and sometimes it came back …We had a total of 6 patients…

Researcher 1: So what did you do with the patients, bring them back [to an outreach clinic]?

Paediatrician 2A: No, no. We got through the session…. muddled through…

Researcher 1: That's the only time it's happened?

Paediatrician 2A: Mm. We've had minor problems. We've had problems getting the stethoscope to work and times when the quality of when one or two of the lines hasn't been working well. I think that's down to B.T. The problem is that this line, we don't use it very often so I think it malfunctions and we don't know about it in time.

Researcher 1: How many link-ups have you had with [The Brompton]?

Paediatrician 2A: One a month, plus the occasional emergency.

Researcher 1: How many months now?

Paediatrician 2A: It's about 14 months

Researcher 1: So that's about 1 in 14 when you've had a disaster.

DGH3

Sonographer 3A. Only just really got the hang of it. It's taken Sonographer 3B1 quite some time. There's been quite a lot of technical problems especially with the link as well. A couple of occasions the pictures haven't been too good, but that's all to do with transmission…It was resolved.

Researcher 1: Did you know what had to be done to resolve it?…

Project facilitator 3: I made a phone call…I spoke to people who put in the equipment…. We had a link-up with them and it was all resolved.

Control hospitals

DGH1: No comments about equipment problems

DGH4: There were some initial technical difficulties in using the telemedicine equipment, which The Brompton telemedicine co-ordinator helped to sort out.

Paediatrician 4B: … There were technical difficulties. I told you that, it's basically to get used to a machine, a new one, it takes some time to build up the confidence, it takes a long time.

Researcher 1: And your ultrasound images that you transfer, have they got colour doppler..?

Paediatrician 4A: They're in colour doppler yes. What would be fantastic would be to connect the machines, the two machines, together.

Paediatrician 4C: That is a possibility actually, because our echo machine ... sort of works as a PC… And you can have a direct transmission through ISDN and you can have the same machine at the other end, you can actually direct the picture on the X-Ray. Because at the moment because the screen is such that it depends very much on what the tilt is, what the angle is. You know, that actually governs the quality of picture that they receive at the other end.

Researcher 1: So they view your screen? I hadn't realised that.

Paediatrician 4C: They view our screen unless we are recording on the video…And they should be able to get it on their screen exactly as we play.

5. Training issues

There were two areas of training which were crucial to the success of the telemedicine service: using the telemedicine technology, and performing ultrasound scanning to demonstrate cardiac anatomy and blood flow. This section covers ultrasound scanning. The clinical members of the project team held sessions in advanced scanning during the early months of the fieldwork programme.

Intervention hospitals

DGH2: This hospital already had a echocardiography machine for the neonatal unit and a second machine was bought for the paediatric department.

Researcher 2: When we set out, did either of you go into The Brompton to have a little trial?

Paediatrician 2B: [The specialist] didn't think we needed to.

Paediatrician 2A: Well we have actually, both of us, certainly have spent… in previous years.... we have been up and given coaching.

Researcher 2: And then, of course, you've been with [the specialist] in the [outreach] clinics.

Paediatrician 2B: Yes, when he comes here we get more practised…we question him.

DGH3: Staff received tuition in neonatal echocardiography, or in fetal heart scanning.

Paediatrician 3A: From a Neonatal point of view, myself and Paediatrician 3C, I think, went up together, I think Paediatrician 3B went up separately. [The specialist] took us on one of his clinics and…he built on what we already knew.

Paediatrician 3B: Well, I mean, whether to ask questions, I had been doing echos for a long time, so I was just, you know, it was a just top-up for me, you know, but purely a person who has never done that course…That one session …it won't be enough.

Sonographer 3A: Yes, we went up to London with one session with [the specialist]. That was really good. We got to get hands-on experience, but it was really quite daunting because it was all a new experience and I felt just one session wasn't enough, so [the specialist] very kindly came down. That was good because we all want to have more experience and doing the links we've learnt as we've gone along really about what they need, about extra use of doppler. So it's been really, really helpful, really good.

Sonographer 3A: We've [since] had a lot of feedback and we have found some problems. [The specialist] has actually showed us some videos from when she was scanning, so it's worked both ways. So it's been a real learning, learning experience, …because obviously looking at the extra views, picks up more problems so we're looking at every baby in more detail now, or we're trying to. So it should pick up a lot more problems…
Obstetrician 3A: I think an absolute important point. I went to one of the courses up at The Brompton which was very good. By what they've done, Sonographer [X] is considerably better than me at hot scanning a heart and I'm sure that a lot of that is because of that reinforcement of actually doing it in that structured and disciplined way almost you're having your own work marked each week [via the telemedicine link up], every time anybody's squirting it up the line and of course it doesn't take very long.

Manager 3: I think one of the points, just listening, which seems to have come up here, is the level of expertise that you have developed. … If you are not here, then somebody else is going to have to develop that level of expertise and is not the telemedicine link the ideal way of reinforcing for new people coming in….

Control hospitals
DGH1: In this hospital, detailed screening for fetal abnormalities, including the fetal heart, was done within the obstetric department. On the paediatrics side, the lead paediatrician for the telemedicine service, who was newly appointed, had recently worked in a paediatric cardiology centre in London.

Sonographer 1 Yes, we did [go to The Brompton], myself and [another] of the sonographers… a half day. We were just really, trying to standardise the views we did so that if we had a case of interest, we wouldn't be showing [the specialist] pictures of weird and wonderful views that she wouldn't wish to see…To be honest the views and things that she was doing were more or less what we would have done as standard anyway. So there's not huge discrepancies ...

Paediatrician 1C: …I think that it [the telemedicine service] has enabled us to become much more expert much more quickly than [Paediatrician 1A] would have found it otherwise. Her alternative was going up to The Brompton twice a month which would have been quite a long way.
Paediatrician 1A:.. I think it's very difficult with paediatric cardiology and you've got to keep a foot in the door somehow. That's healthy, I can't afford the time to go up to The Brompton every month, as you can imagine ... it would be lovely, but I can't afford that time.

DGH4: This control hospital delayed utilising the telemedicine service until after it had purchased an echocardiography machine specifically for the neonatal and paediatric units.

Paediatrician 4B: …so we had to go on training and we were not actually competent ourselves how to do it and there were lots and lots of training issues....

Researcher 2: …you presumably are now doing many echos for yourselves for babies and children. How did you get up to speed, with the training for using the equipment or had you come with expertise…
Paediatrician 4B: I had to go to sessions on cardiac echocardiography in [another London paediatric cardiology centre], so I did the course.

> *Paediatric trainee: Well I did some echos under supervision…there as well…. I did a little bit, I'm not really confident to do it by myself.*

Note that these paediatric consultants also received tuition during the outreach clinic sessions.

6. Ultrasound and echocardiography scans for telemedicine transmission

This section covers the patterns of practice adopted by the clinicians in transmitting scans via the telemedicine service.

Intervention hospitals

DGH2: A business manager began by observing that in past years, some of the transfers of neonates to London were specifically to have an echocardiogram.

Researcher 1: You always scan live don't you [when holding teleconsultations]? Have you considered doing a video and showing it [to the specialist]?

> *Paediatrician 2A: …One of the principal attractions to me [of live scanning], is ...he'll tell you what he wants to see and he'll guide you and this I've found is very, very helpful.*
> *Paediatrician 2B: I've shown him tapes.*
> *Paediatrician 2A: I mean that, as you would say, that probably [transmitting tapes] is a very efficient way of doing it…*
> *Paediatrician 2B: … sometimes they [the patients] are not very cooperative....*

Researcher 1: How many patients do you think you show [present] in an hour?

> *Paediatrician 2B: We finish by 4.15, so in that hour and 15 minutes we show about 5 patients. That's not bad... That's 15 minutes each.*

DGH3:

a) Fetal ultrasound.

Most women undergoing fetal screening were identified according to the Obstetric Department's protocol for high risk of a fetal heart anomaly.

Researcher 1: And as you say a lot of them you're just transferring across because it's part of
the protocol. That's right, you're getting them confirmed.

> *Sonographer 3A: That's right, yes…. Because we never used to scan these ladies, you know, in detail. They always used to go up to London so it's extra work for us.*
>
> *Sonographer 3A: When we scan patients, obviously we take them into the room with the video. Video the bits of cardiac views, save them on videos and then we get in touch with [The Brompton telemedicine co-ordinator] and we organise [the telemedicine session]. It works out about once a month on a Thursday morning and then …[the project facilitator brings the telemedicine trolley down from the floor above], sets it all up for us and then we playback all the video cases. We have live transmissions.*
> *Unidentified speaker: They're never live on the patient?*
> *Sonographer 3A:… We've done a couple of live links where we found cardiac problems, really major, major problems. So they've done the link for us the next day. We've had a live link when we scan the patient, they can see what's going on and they can have a conversation with the patient. That's been really helpful.*

b) Neonatal echocardiography

Paediatrician 3C: Paediatrician 3A and I [who both do the neonatal echos] have audited ourselves…

Paediatrician 3A: All done, we worked it out yesterday, we've done about 80 echos in the last 5 months…. of which, we've only really relayed in the neonatal unit about 7 or 8. And that's partly not because we don't want to relay each one, it's because we're pretty confident of what we're seeing, as I said we're only relaying those that may need a clinical input from the cardiologist. For instance like ligation of a duct, or I had a baby with dextracardia and I wasn't quite sure what I was seeing and that was a link-up. That was a real-time link-up. We would often have babies on a week end or at night. It's impossible or difficult to link-up live and we've had to videotape those and then Paediatrician 3B has actually relayed them up during the day time. So we have had several types of relays which have been mainly videotaped ones, but we have had one or two real-time relays.

Paediatrician 3C: In particular one we did, the real time, one was the transposition, which I think was extremely helpful. I can't remember the individual history, but clinically it was cyanotic heart disease and we thought it was transposition confirmed by the cardiologist from the other end and the baby was transferred the same morning and had a very good outcome…

Paediatrician 3A: I mean, it depends on our confidence if we know what we're seeing, we're not going to then spend half an hour relaying it if that half an hour can be spent in actually stabilising the baby and then transferring it when we're confident in what we're seeing and I think that's what other departments will find. As their confidence improves, they're using the link probably for the ones where they're not sure.

Control hospitals

DGH1: As this control hospital had a special care baby unit, babies diagnosed before birth with suspected congenital heart disease were frequently delivered in a London hospital close to a paediatric cardiac centre. Consequently, fewer babies with serious disease were delivered locally when compared with the other hospitals. This hospital also did not have a dedicated echography machine for neonatal use.

Paediatrician 1C: I don't think from the in-patient point of view that it has made a huge difference, there must have been a few babies I suppose in special care we used cardiac echos on but I'm not sure we can demonstrate its application has made a great difference to the outcome of life.

Paediatrician 1A. But the only thing I was going to go back to, is equipment being in the right place really, just that with babies on special care, what I tend to do is video all my echos anyway…[with the use of a echocardiography machine from the cardiac department.].

Paediatrician 1C: Most of the children who we would have otherwise probably sent to The Brompton are ones [seen in] outpatients and again numbers haven't been enormous.

Paediatrician 1A: They don't actually need to be seen…. you don't need to send them all off to the specialist.

Paediatrician 1A: …we did try and have a Telemedicine session … before Christmas and we couldn't get through, there wasn't space. So in the end I actually sent my echos that I had, couriered them… to [the specialist] who then looked at them and

> *wrote me back a letter…. the pictures were absolutely fine. I think you become very confident when you're doing a thing every single day, but when you're doing so many other things, you don't feel so . .. you've got to try and keep your confidence*

DGH4: This control hospital referred both neonates and children via the telemedicine service.

Researcher 1: And what do you do now with the Telemedicine? Do you do a live scan or do you record them in advance?

> *Paediatrician 4B: We do a live scan .... mainly we do the live scans. On two occasions, because the baby was sick… I recorded [the scan] on the Unit and then I had to take the scanner down stairs and talk to the specialists.*

Researcher 1: You didn't take the baby downstairs.

> *Paediatrician 4B: No, because that baby was quite sick so I couldn't.*

Researcher 2: Your equipment is on the floor below isn't it? And the babies are up here?

> *Paediatrician 4B: Yes, the babies are on this floor.*

Researcher 2: But did that work satisfactorily?

> *Paediatrician 4B: Yes.*

Researcher 1: Do you keep a video record of the [live] scans that you do over the telemedicine link?

> *Paediatrician 4A: We could, but we don't.*
>
> *Paediatrician 2B: Whatever we do in that [virtual] clinic, no, but whatever we do in our Unit, yes… all of these are recorded.*
>
> *Paediatrician 4A: It's not that we can't do it. I don't see the point in doing it. The only reason why we do it is to show it to him. If he's seeing it on a live link there's no point...*

Researcher 1: Has anybody ever said to the patients 'Come to London and I'll do an echo there'?

> *Paediatrician 2B: Not any more.*

Researcher 2: Can I just ask, do you actually get quite a sense of satisfaction after one of those clinics.

> *Paediatrician 4A: Oh yes. Definitely. Well I'm thrilled because half the patients we don't have to see them again and I write down exactly the clinic letter .. dictate. Letter to GP and everybody I need…. I write it down after the clinic. So you see it works like a real clinic.*

7. The telemedicine service complementing existing outreach clinic services

Intervention hospitals

DGH2

> *Manager 2: Obviously Cardiology has a really long waiting at tertiary centres…We always have more patients queuing to see a cardiologist than they can see in any one visit. So what Telemedicine seems to do is speed up the diagnoses and the referral for a group of children who may well unnecessarily wait…But a child with an innocent murmur, you know, the parents are very anxious, so to get a diagnosis or a reassurance more quickly, obviously helps the parents but also keeps our waiting list down for these tertiary clinics. So I think our experience is that the parents have appreciated it and it does take those patients off quicker.*
>
> *I think in the whole project we used it on about 44 patients… Some of those probably would have been additions to the waiting list, we haven't necessarily removed them we just didn't necessarily put them on and also the waiting list, is affected a lot of it's follow-up. You're not getting new patients. They're children that have been seen,*

> *diagnosed, had surgery and are then coming back to see [the specialist] here, just for follow up. So we've probably affected the new patient waiting lists more than we have the follow-ups, would that be true?*
>
> *Paediatrician 2B: That is true. Probably 4 [new] patients a month .. sometimes nil or sometimes more.*
> *Paediatrician 2A: We've seen 22 patients in 3 hours sometimes or about 7 patients an hour [in the outreach clinics]. We see about 4 an hour [with telemedicine].*
>
> *Manager 2: We'd need a dedicated session and Paediatrician 2B's sessions that he's contracted for are fully used up. The same as all the Consultants, they don't have spare sessions. So you'd be looking at extra funding or if you were doing bigger clinics, the four that you do you can fit in, lunchtimes.*

Researcher 1: …Couldn't the [telemedicine sessions] release you from sitting in [the specialist's] outreach clinics?

> *Paediatrician 2B: [The outreach clinic] is purely educational…the clinic will run even though I am not [there].*
> Paediatrician 2A: *Well, we have an extra opportunity to have a consultation with [the specialist]… I personally have found it very helpful because .... it helps me with my specialist skills …*

Researcher 2: Have you reached the point now where the [telemedicine] clinics are sort of quite routine and you feel yourselves comfortable about presenting the patient?

> *Paediatrician 2A: Well it's just the same as being in [the outreach] clinic.*

Researcher 1: The other thing I noticed in the outreach clinic, [the specialist] always feels the abdomen and the pulses in the groin and that. Does he ask you to do that for him.

> *Paediatrician 2B: We have done it before and just tell him ....The patient is seen by me before all that is being done.*

Researcher 1: So there's nothing that [the specialist] really needs to do hands on. He's got the stethoscope, OK. The parents are there as well.

> *Paediatrician 2B: Yes, the parents are there, doctors are there, the patient. It's a full consultation as effective as if he is here …*

DGH3: As this intervention hospital did not use the telemedicine service for paediatric referrals, the service had no impact on the existing outreach clinic arrangements.

Control hospitals

DGH1: This hospital did not undertake routine telemedicine sessions with patients presented live; instead pre-recorded videos of echocardiograms were transmitted.

DGH4: The telemedicine clinics include live scanning undertaken by the district paediatricians.

Researcher 1 .. Could I ask you first whether you feel that having the telemedicine equipment and the opportunity to use telemedicine has affected your clinical practice.

> *Paediatrician 4B: Definitely in some cases, especially in the cardiac, echo feature of the telemedicine …. We avoid a transfer in which we establish some medication, so it definitely has got some effect, and also cutting the waiting list for these cardiac cases. We are doing around 4/5 in one [telemedicine] session … Many of the cases we get his decision, we get the diagnoses and sometimes he likes to see himself one*

or two cases like that. Also advice on medication for some babies, so it definitely has advantages for us.

Researcher 1: [The specialist] did a very large clinic on Friday mornings here. Has the number of cases that you book for him in the outreach clinic changed?

Paediatrician 4B: Yes. It used to be about 28 now it's down to only 10.

Researcher 1: How do you select the patients for that [telemedicine] clinic? Is it on the heart condition or is it on their age…?

Paediatrician 4B: No, the age cut-off limit our machines [ultrasound] can't do more than 7 or 8… It's either sort of follow-up patients or the ones where we've done a scan and found some abnormality.

Researcher 1: And when you identify that they're going to go to this clinic do you say to the parents 'We're going to be looking at our main consultant over the television link'.

Paediatrician 4A: Well we have a letter.

Researcher 1: Has anybody ever refused?

Paediatrician 4A and Paediatrician 4B: No.

Paediatrician 4B: We done a nice letter to parents, how telemedicine will work and how we'll do these things. A nice explanatory reference letter and it went out to the parents. It goes quite in advance.

Paediatrician 4A: About two to three weeks in advance…

Researcher 1: Is confidentiality an issue do you think?

Paediatrician 4A: No.

8. Urgent requests for advice

As expected, the district hospital clinicians needed to hold few urgent consultations with specialists about very sick babies. The clinicians noted the benefits of not having to transfer the babies to London for both the health of the baby and the financial savings of avoiding an ambulance transfer. But there had been occasions when urgent advice was not available outside normal working hours

Intervention hospitals
DGH2

Paediatrician 2B: You can get it [specialist advice] if you have an emergency. You can get somebody to come on line. We have done that two times with babies from the baby unit, who would have otherwise travelled to London….

Manager 2: Just that one scan saves us the transfer fee of an ambulance and the nurse and doctor time to go there and go back and of course the outcome for the baby.

Sister Baby Unit 2: Once you've actually ruled out that it's not a cardiac problem then you can start looking elsewhere and investigating sooner, rather than wasting hours up to Brompton and back and you've wasted a whole day, when you can do telemedicine. I mean, it does work out really beneficial. Because, like if there's anything normally wrong cardiac it's an emergency and to have answers quickly and to be able to initiate treatment quickly is the best thing for the baby and for the family and everything is very, very beneficial

DGH3

a) Urgent fetal medicine cases

Sonographer 3A: Yes. We have picked up a few more problems … Myself and my colleagues have become much more confident in obtaining the views and even

looking at the four chamber view…So if we do suspect there's a problem, we will video it now regardless and try and get the link as soon as possible or if any doubt we make a direct phone call and try and get the lady to go up to London to see [a specialist].
Paediatrician 3C: So are you looking for four chambers?
Sonographer 3A: Yes, yes. Now we're much more confident, we try to look at every patient.
Paediatrician 3A: Even the low-risk patients?
Sonographer 3A: Yes, there should be more pick-ups.

b) Urgent neonatal cases

Paediatrician 3A: …we would often have babies on a weekend or at night. It's impossible or difficult to link-up live and we've had to videotape those and then Paediatrician 3B has actually relayed them up during the day time. So we have had several types of relays which have been mainly videotaped ones, but we have had one or two real-time relays.

Control hospitals
DGH1

Paediatrician 1b: I mean advice is always there, you can always ring them up. An echo isn't the be all and end all really, it's just, you don't necessarily want to stick a premature baby in an ambulance and send them off for an echo there. … It was really more logistics of organising it. I was on call that night and then had to get to the clinic first thing in the morning. I spoke to the [duty registrar] overnight and they didn't have access to the telemedicine equipment at The Brompton …

DGH4

Paediatrician 4C: On one occasion it happened when I was on call... calling them for an emergency consultation [`We had one child and I wanted to do another echo with someone at the other end.'] and I was told that the … people on call on that night said they were not aware of how to do it. So I felt that, you know, this is something when the video telecommunication was something that would have avoided that transfer.

9. Importance of personal relationships between hospital staff and specialists

Intervention hospitals
DGH2

Paediatrician 2B: You want to have somebody like [our regular specialist] who's very sound and used to us. Because we have had other cardiologists. It's not the same… We had to bring the patients back on both occasions …, or re-present them at a later stage. The level of confidence they have with you and you have with them has to be..
Paediatrician 2A: The best . That's not a function of telemedicine actually.
Paediatrician 2B: That's what I'm saying there has to be a very sound guy on the other end.

DGH3 No specific comments

Control hospitals
DGH1

Paediatrician 1C: Before we had the telemedicine equipment we didn't have anyone here who was really trained in doing cardiac echos and it was coincidence that we got Paediatrician 1A here at about the same time. Of course, that made a huge difference. So it's a bit difficult to sort out how much of a difference is due to having someone who was trained and had a good link with The Brompton already and how much was due to the fact that we had the equipment here, so we could discuss images with them.

DGH4

Paediatrician 4B:…Because we have a sort of, personal relationship with [The Brompton].

Researcher 1: So you've got a good long-term working relationship with each other.

Paediatrician 4A: That's right, a trust. Yes.

10. Co-ordination of the routine telemedicine sessions

Intervention hospitals
DGH2

Researcher 1: Do you have a nurse organising [telemedicine sessions] as you do in outpatients, because they're very efficient aren't they?

Paediatrician 2A: I think that's probably something we ought to do. I've often felt it would be nice to have somebody.... because you're fiddling around, it's very crowded [in the telemedicine room] and full of cuddly toys and all sorts of stuff and you can hardly move in there and you're trying to juggle X-rays and ECGs and patients. It would be nice to have somebody there who could get it all organised.

Paediatrician 2B: That's very true.

DGH3: [See section 6 for the comments on organising the fetal medicine telesessions.]

Control Hospitals
DGH1

Paediatrician 1A: Well there is a system now for bookings. [A Brompton secretary] actually has the diary that we book it through.

Unidentified speaker: There is a diary system….we have a nominal slot that we can take up each month if we wish, but obviously if something crops up more urgently we can negotiate the slot.

11. Costs for the telemedicine service borne by the district hospitals

Intervention Hospitals
DGH2

Manager 2: …Patients on the waiting list aren't necessarily people who would benefit from, you know, a scan or telemedicine. I mean it doesn't feel like enormous numbers have benefited. But to us, from our perspective, it feels expensive. Because at the moment we've got [the specialist and Paediatrician 2B] doing it and [Paediatrician 2A]. Free will, goodwill. So it hasn't cost consultant time because they've fitted in these extra clinics, so we haven't costed, if we had just went on along,

… I'm already in a predicament where they've booked clinics up for the rest of the year and I haven't got any research money left to pay for the telephone bills any more, so already into the next year, just for the quarterly bills, I'll be £2,000.00 short. Then the following year my maintenance contract will be due again, so that's another £3,500.00 in that third year, so already I'm wondering where am I going to find this money to keep this going for 4 patients a month. So it feels quite expensive and that's given that [the consultants] will still do it for nothing, if you like.

Researcher 1: Well have any of the other Directorates been interested in using it?

Manager 2: We haven't actually advertised it have we?

Paediatrician 2B: We have actually. We do have another facility here [in the postgraduate centre].

Manager 2: I suppose they need the link the other end to be set up before they actually think about using it. …. I mean, I'm not sure how pro-active we would have been if you hadn't come along with the research project…because it would have been enormously expensive to set up and the Trust have actually set up telemedicine in the postgraduate centre, so already now when I'm sniffing around looking for this extra money I'm being told 'Well we've already got the facilities and the line over there, why don't you use it'. The difficulty for us is that we could use it to take a video over but take scanning equipment, even for outpatients, you'd ruin your equipment, keep moving the scanner…and the whole benefit is for the neonatal unit to do it with the babies there. You could walk a 5 year old over there, but you couldn't keep moving the scanner, so you know, there are practical issues to taking it a lot further.

Manager 2: We'd need a dedicated session and Paediatrician 2B's sessions that he's contracted for are fully used up. The same as all the consultants, they don't have spare sessions. So you'd be looking at extra funding or if you were doing bigger clinics… Well at the moment because of the link support I'm just going to absorb the costs. It will be something else I can get paid for. It will be instead of buying a piece of equipment I will just make sure that that's covered, because for all the reasons Paediatrician 4B's explained about the satisfaction for that small quality group and it does seem silly to have the equipment there that you're given and not using it. So I think the idea is I will have to try and absorb the costs at the moment. But I will explore other ways, I will go to a few fund raising routes to do that. But I also will explore what's available at the postgraduate centre and see whether we can have the type that we've got a bit more to spread the costs around

Paediatrician 2B. It's very difficult, quality improvement. But the quantity is very small. So when your quantity is not high your cost is related to that. Cost effectiveness.

Paediatrician 2A: … The fact of the matter is that the... line rental is quite expensive.

DGH3

Paediatrician 3A: The equipment is obviously the cost is coming down, but I think one of the worries that I have is that you have this equipment and it's covered by a service contract for the time of the Trial and maybe a little bit longer. Thereafter, if you start developing the service and expect this equipment to work and then all of a sudden there's a major problem with it or it needs updating, it's just the capital cost or maintenance cost from the Trust itself may become an issue.

Researcher 2: …your maintenance contract goes on for another eighteen months.

Manager 3 But during that period of time it's proved its worth or it hasn't proved its worth hasn't it. If it's use has actually expanded within that eighteen month period then it will justify it's existence or not…. If it's sitting in the cupboard for the next eighteen months then it's not going to.

Paediatrician 3A: I mean, for us it would be an issue of "Do we replace the telemedicine equipment?" or "Do we get a better echo machine?" - that will be the big debate for us, I believe in two years time, three years time maybe.

Control Hospitals

DGH1

Researcher 1: What about the phone bills? Do they go up to you [for payment from your budget]?…

> *Paediatrician 1A: No, they're not, it's coming out of the Central Trust budget. They haven't started to claim, it's all about sorting it out and I don't think they will, I don't think they can cope with that….*

DGH4
Researcher 2: …I know when the equipment was purchased and given to the four hospitals, we also covered [part of] the cost of the maintenance contract, but the hospitals were expected to find the installation charges and the call costs. Has this been a concern to you, the running costs of the service?

> *Paediatrician 4A: I think one of the advantages we have is, because the whole budget is contained in the department, so we are able to juggle about, whereas if you have combined directorates, you will run into problems.... It costs us about £1,400.00 to maintain it.*
>
> *Paediatrician 4A: The more we use it, it becomes more cost-effective. I think our problem is the shortage of space.*

12. Educational benefits of the telemedicine service

These are three illustrative comments on the educational potential of the telemedicine service.

DGH2

> *Sister Baby Unit 2: It's been wonderful. The times that we've used it, it's been very, very interesting. A lot of the SHOs and the nurses have been very interested. It's been very educational and quite a few of our babies have benefited greatly from it.*

DGH3

> *Unidentified speaker: There is also a wider education thing, which is that you know we are able to teach people echo skills because we are developing that, so you will notice that with your own colleagues that they are interested in improving their skills, which you can't quantify I don't think.*
>
> *Obstetrician 3A: It's like a lot of these skills unless they're being checked and repeated again and again…you can image if you've just had the training course, everyone's got great enthusiasm on day one, but it dwindles and fades over time. But the telemedicine link actually reinforces that, week in, week out, and maintains standards and also allows a way of teaching new tricks and new skills. So okay you've got to that level, well have you tried using the colour flow on that, how do you use pulsar on that? Oh we'll give that a try next time. So it acts as continuous reinforcement and upgrading, which I think is something that shouldn't be lost sight of.*

Despite the pessimism expressed by at least two business managers over the continuation of the telemedicine service because of financial implications, the service was still operating in all four hospitals 2½ years after these discussions were held. The up-to-date situation is outlined in the Epilogue.