ABSTRACT. Objective. To develop and to assess the clinical impact of a near-television quality home digital videophone system (Integrated Services Digital Network [ISDN] 64, 320 × 200 resolutions, 10 to 12 frames per second), which would provide respiratory care specialists’ resources to primary care physicians and their pediatric patients receiving home respiratory care.

Method. A prospective study comparing the preceding 6 months and following 6 months of implementation of a videophone system on seven pediatric home respiratory care patients (group I) and a prospective analytical study of three patients (group II) being introduced to home ventilatory care were carried out. Clinical effectiveness and time-saving benefits were studied.

Results. There were large reductions in the number of house calls by the physicians (from 5 to 0), unscheduled hospital visits by patients (from 24 to 5), and hospital admission days (from 22 to 10), with a fivefold increase in phone calls (from 11 to 58) in group I. This reduced the net number of hours spent by both patients and physicians in unscheduled medical care by 95 hours for the patients and 51.2 hours for the physicians. A total of 45 videophone calls, of which 27 were related to mechanical concerns and 18 to medical concerns, were made in group II. There were 7 mechanical and 10 medical problems of clinical significance, but all were directly handled by physicians by videophone. The majority (35 of 45) of videophone calls were made in the first 3-month period, indicating a decrease in nonspecific concerns after this period. The specifications of the system we used were found acceptable by both patients and health care professionals. The system seemed to be useful in effectively using the time of specialists and in relieving the anxieties of families. No deleterious effects were noted. The current initial cost is substantial but rapidly falling. The running cost is similar to a regular telephone bill when one ISDN 64 line is used.

Conclusions. The videophone system using ISDN 64 can now be considered a practical and effective tool to recruit specialist resources into home care and to improve the quality of pediatric home ventilatory care. This study encourages the use of videophones to help establish designated home care support systems that may extend beyond national borders and time zones. Pediatrics 1997; 99(1). URL: http://www.pediatrics.org/cgi/content/full/99/1/e1; home care, videophone, telemedicine, Integrated Services Digital Network.
are a limited number of specialists in pediatric respiratory care and an embarrassingly insufficient number of pediatric critical care units. According to a recent survey conducted by the Japanese Society of Intensive Care Medicine (1993), there are only 158 pediatric critical care beds (compared with 9214 ICU beds, 2000 coronary care unit beds, and 2741 neonatal intensive care unit beds). Many children who require long-term mechanical ventilation are cared for in regular pediatric wards. Patients needing special care converge in tertiary centers, often far from home, to undergo long-term hospitalization for chronic respiratory treatment.

The number of people who understand the need for home mechanical ventilation and who could actually implement such a program is small. This number is further limited by the licensing system in Japan, because only physicians are allowed to operate ventilators in hospitals. There is no system for respiratory therapists. Pediatric home respiratory care is organized and implemented directly by hospital-based pediatricians on an individual basis. The family expects very little in terms of medical help, even in the form of visiting nurses or other public services, once respiratory care such as endotracheal suctioning or ventilator use is involved.

The current reimbursement plan by the national insurance system in Japan is structured in such a way that home mechanical ventilation costs significantly more (at least three times) to a patient’s family than in-hospital care. Pediatricians are often hesitant to select home care, even when the family wants it. The mandatory monthly hospital visits required by the health insurance plan are counterproductive to the nature of home care.

A national survey we conducted in 1992 found that the biggest frustration of pediatricians who have candidates for home respiratory care was the unavailability of a support system by respiratory care specialists. The major concern of families who have children who are receiving ventilation at home was a fear of complete isolation from the hospital specialist. Most family physicians and health care personnel nearby are not familiar with respiratory care, so patients must depend on tertiary centers farther from home.

METHODS

Videophone System Modifications for Home Care Use

A stand-alone color videophone with a built-in fixed-focus camera (Picsend R; NTT-Hitachi, Tokyo, Japan) was modified for home respiratory care. This videophone is not based on personal computer operation or Internet technology, thus no keyboard operation or computer software knowledge is required. A simple remote camera operation control system (Aishin Cosmos Inc, Aichi, Japan) using telephone push buttons for panning and zooming a home video camera or detachable handy charge-coupled device camera was set up in the patient’s home. This enabled us to control from the hospital the video camera connected to the videophone at home (Figure).

This system can transmit near-television quality (320 × 200 resolution) pictures at 10 to 12 frames per second. Although motion is still jagged, the oscillatory movement (up to 40 breaths per minute) of an airway pressure manometer can be observed. The quality of sound transmission is excellent, but there is a delay of approximately 0.5 seconds from the picture.

The videophone we used offered several additional features. The fine still-picture mode can transmit high-resolution (704 × 480 resolution) pictures with a quality good enough to interpret routine chest radiographs or to examine skin color and other patient conditions. Videotaped pictures such as an echocardiograph or the operation manual of ventilators can also be transmitted. A specially made microphone can be attached for stethoscopes. The conference function enables discussion between up to four different locations. These additional functions, however, were seldom used in home care.

Several clinical conferences with patients in the PICU who were receiving respiratory care were held using this videophone system before home care application to evaluate the clinical feasibility of the quality and speed of images of this videophone. Videophones at our PICU, our physician’s office, children’s hospitals in the United States (Los Angeles, CA) and Osaka and Chiba, Japan, and the work stations of technical service providers were connected. Six pediatric intensive care specialists, three pediatric cardiologists, two pediatric pulmonologists, and two medical engineers participated. The general consensus was that this system was capable of transmitting clinically acceptable levels of chest wall movement, ventilator movement, chest radiographs, echocardiography, fiberbronchoscopy images, and importantly, the emotional expressions of family members.

Study Protocol

The study was conducted between September 1994 and March 1996. The study protocol was approved by the Institutional Re-
A total of 10 families who were living in the ISDN 64 public telephone network-accessible area and who were managed under the home respiratory care program at the Department of Anesthesia and ICU, National Children’s Hospital (Tokyo, Japan) were enrolled. Group I consisted of 7 of our patients (ages 3 to 24 years) who were already receiving home respiratory care (duration, 2 to 13 years) at the time of videophone installation. Group II consisted of 3 patients (10, 14, and 20 months of age) who were discharged and transferred to home care with this system. The clinical characteristics of the patients are summarized in Table 1. The distances between our hospital and the homes of patients ranged from 10 to 500 km.

Videophones were treated exactly the same way as regular telephones. The videophone installed in the PICU could be answered by any PICU physician or nurse nearby. Patients or members of their families were allowed to call the PICU anytime they wanted. Patients or members of their families were allowed to call each other or technical service providers when they thought it was necessary. Technical service providers were allowed to call the patients’ homes or the hospital. No routine or special calling time arrangements were made among participants. The videophone system and its installation fee were provided to the family free during the study period, but the families were asked to pay the monthly telephone charge.

All the unscheduled hospital visits, telephone calls, and videophone calls made by patients or from the hospital and/or technical service providers were logged and analyzed. The parents, physicians, and technical service providers involved were asked questions regarding the degree of satisfaction with this system 6 months after the system was introduced. Only phone calls initiated by the patient or care giver were counted, and a series of videophone calls regarding one episode on 1 day was counted as one phone call. Patients receiving home care were required to visit the hospital every month (routine visit) according to the Japanese national uniform fee schedule, but those visits were not counted in this study.

The general feelings of the family toward this system, which were voluntarily expressed during videophone communication, and both positive and negative concerns toward this system gathered at the time of routine hospital visits were recorded and summarized. Feedback from technical service providers was also recorded and summarized.

Statistical Analysis
A nonparametric Mann-Whitney U test was used for statistical analysis because of the nonnormal distribution of data (numbers of phone calls, unscheduled hospital visits, and hospital admissions). P < .05 was considered statistically significant.

### RESULTS
Phone calls, unscheduled outpatient visits, and hospital admissions before and after videophone installation are summarized in Table 2.

#### Number of Videophone Calls, Hospital Visits, and Admissions

**Group I (Patients Already Receiving Home Care at Videophone Installation)**

The number of phone calls (via regular telephone) was 11 before the introduction of the videophone system, but there were 58 videophone calls after installation of the videophones. A fivefold increase ($P < .004$) in phone calls was observed in this group. There were 24 unscheduled hospital visits before installation, but the number of unscheduled hospital visits decreased to 5 visits after the installation of the videophone system. The number of days the patients were hospitalized was 22 days (4 admissions in three patients) before the introduction of the videophone system. This decreased to 10 days (two admissions in two patients).

Two patients (both older than 15 years) who never had unscheduled hospital visits in the previous 6 months had no unscheduled hospital visits, but the number of phone calls increased from 1 to 28 times after the installation of the videophone system. The majority of these calls were friendly calls expressing the general feelings of patients or family members to physicians.

The remaining five of seven patients already receiving home care required a total of 24 unscheduled hospital visits and 4 hospital admissions in 6 months before installation of the videophone. There were 11 medical telephone calls, of which 9 ended in outpatient hospital visits. After the installation of the videophone system, there were 30 videophone calls by these five families, of which 14 were about medical concerns, 6 mechanical concerns, and 10 friendly calls. After the installation of the videophone system, the number of unscheduled hospital visits significantly decreased to 5, an 80% decrease ($P < .01$). The number of admissions to the hospital was 4 (a total of 22 days) before and 2 (a total of 10 days) after the videophone introduction, but the decrease was not statistically significant.

Out of 30 videophone calls, 14 calls were for medical problems, all of which had clinical significance. Three calls were related to a recurrence of seizures that occurred in one patient. Two episodes were treated at home under videophone supervision, but 1 call ended in hospital admission. Seven calls were related to worrisome high fever, all of which, except 1, were treated at home under videophone supervision. Blood tint and tenacious suction materials were the concerns for videophone calls on another 4 occasions. There were 6 calls related to mechanical concerns, of which 4 were related to the malfunction of heated humidifiers and 2 to the overheating of an air compressor. These were handled by videophone by a physician on call and followed up by 2 nonurgent house visits by the technical service provider. There

<table>
<thead>
<tr>
<th>Patient</th>
<th>Age, y</th>
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<th>Reasons for Home Respiratory Care</th>
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<td>Chronic lung disorder</td>
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* N/A indicates not applicable.
were 12 semiurgent technical service visits during the previous 6 months, but these decreased to 2.

**Group II (Three Patients Sent Home With Videophone Systems)**

Three patients were sent home with videophone systems from the beginning. There were 45 video-phone calls in the first 6 months, with only one unscheduled hospital visit. No patient in this group was hospitalized during the study period. Most (35 of 45) videophone calls were made in the first 3 months. Of 45 videophone calls, 27 were related to mechanical concerns, and 18 were related to medical concerns.

All the mechanical troubles were directly handled by physicians by videophones, and no urgent technical service was required. Of 27 calls related to mechanical concerns, there were 7 actual mechanical troubles: 2 related to the air compressor, 4 related to the breathing circuit, and 1 related to the function of the ventilator itself. The other 20 calls were general concerns about abnormal sounds or vibrations or the operation of the ventilator. These diverse calls were concentrated in the first 3 months.

There were 18 calls related to medical problems, of which 10 were of clinical significance. Two calls were related to a recurrence of seizures that occurred in one patient, and 3 calls were related to high fevers, all of which were treated at home under videophone supervision. Blood tint and tenacious suction materials were the concerns for videophone calls on another 5 occasions, and they were visually ascertained to be nonsignificant. The other 8 phone calls were for reassurance about the children's conditions.

**Time Benefit Analysis**

A potential time benefit analysis was performed based on the figures reported in a time study of our hospital.\(^\text{10}\) It was estimated that a physician spends 1 hour for one outpatient visit, 2 hours for one hospital admission day, 4 hours for one house call, and 15 minutes for one videophone consultation. House calls for technical support by the supplier were estimated to be 4 hours. A patient and family were estimated to spend 5 hours for one outpatient hospital visit, including preparation, commuting, and waiting time.

The total time physicians spent on 58 videophone consultations was estimated at 14.5 hours. This was an 11.8-hour increase in the time physicians spent on phone calls compared with the previous 6 months. There were 11 phone calls, 25 unscheduled hospital visits, and 5 house calls in the previous 6 months. There was a 100% decrease in house calls (5 to 0), which took 20 hours less of the physicians’ time, an 80% decrease in unscheduled hospital visits (24 to 5) for 19 hours less, and a 50% decrease in hospital admissions (22 to 10 days), 24 hours less.

Thus, a total of 51.2 hours of the physician’s time could be allocated to other patient care during the

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*P indicates number of phone calls in the month; O, number of unscheduled outpatient visits in the month; and A, number of days admitted to the hospital in the month.

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TABLE 2. Phone Calls, Unscheduled Outpatient Visits, and Hospital Admissions Before and After Videophone Installation
6-month period the videophone system was in operation. The time saved by patients and their families by avoiding unscheduled hospital visits was estimated at 95 hours. The absence of urgent service calls by technical service providers (12 to 0) saved an estimated 48 working hours of technical support.

**Hardware Costs**

The hardware for this videophone system cost about $6000 to purchase or $1000 initial installment plus $150 per month to lease at the time of this study and was substantially more expensive to install than a regular telephone. The cost of this system as of September 1996 had been substantially decreased to $2000 to purchase.

The running cost in terms of the telephone bill using one ISDN 64 line, as in this study, is similar to that of using a regular telephone in Japan.

**Evaluation by the Families**

Spontaneous and actively gathered comments from the families indicated that none of the patients or family members involved in this study wished to discontinue the use of the system during the study period. Rather, they all wanted to extend it. They found the videophone system easy to use and extremely helpful in easing the stress of the care givers. The families reported a sense of immediate relief from anxiety related to the technical aspects of home ventilation and the decreased workload related to fewer hospital visits.

Communication between different families using home ventilation was facilitated and was an unexpected benefit of this project.

The high initial installment cost ($1000) was the only major concern. There were minor complaints regarding the hardware, especially difficulties found in direct videotaping and occasional functional instability experienced during the hot and humid summer season. Concerns about invasion of privacy expressed before the introduction soon dissipated as the families realized that they could use the system exactly the same as a regular telephone.

**Feedback From Technical Service Providers**

The major concerns of the technical service providers for a system of this type were the quality of the picture and the versatility of the system. The system was able to allow them to service the respirators without making house calls based on videophone images of the movement of the manometer, readings of the operation panels, and mechanical sound. It was thought that the current system with remote camera control possesses the capability to eliminate most (up to 70%) urgent home visits. They thought that the establishment of a nationwide service network could be justified if the initial cost of the hardware declined significantly.

**DISCUSSION**

A videophone system for home care using a public digital telephone network, ISDN 64, was shown to have the ability to transmit clinically useful data on both medical and emotional aspects of home care. The amount of time saved with this system by health care professionals, patients, and their families was significant. Specialist resources can now be used more effectively to improve the quality of pediatric home ventilatory care.

The system is not aimed at eliminating direct physical examination or evaluation of patients. Instead, we used this system to facilitate the involvement of pediatric respiratory care specialists to help decrease the stress and anxiety of patients receiving home care and their families. Some may argue the value of this system because of its lesser quality and speed of picture transmission compared with a regular or high-definition television system using a higher transmission network (ISDN 1500) or personal computer–based technology. Although the use of such technologies is preferable from a purely medical point of view, it would add significantly to the cost and limit its availability to the public. We thought that the quality and speed (320 × 200 resolutions, 10 to 12 frames per second) of this system were sufficient to be used in patients receiving home care.

Improvement in the physician-patient relationship and the facilitation of communication between patients receiving home care were observed. The strength of the physician-patient relationship existing in our home care setting may well have been both a cause and an effect of the success of the system. Patients felt close enough to make numerous calls to the physician, even calls about mechanical problems, which usually would have been made to the technical service providers. This, as a result, reduced the number of urgent technical visits. The videophone calls made patients feel closer to each other, and several patients and their parents started talking to each other for mutual support and reassurance about their own conditions.

The limited trials with other institutions, including one in the United States, showed the favorable potential of this system in eliminating national borders and time zones. Specialist consultation about a rare condition in Japan (eg, cystic fibrosis) could be obtained without imposing the patient stress of traveling or the risk of getting infections.

A telephone with moving pictures is far more effective in conveying information than a regular telephone. It is, however, not easy to compare the actual effectiveness of videophones with regular telephones in a home care setting. Not only the devices, but the way they are used, significantly affects their effectiveness.

Patients receiving home care and their families are very familiar with their conditions, and it is usually their last resort to call the physician. All the phone calls in five patients from group I ended in unscheduled hospital visits or admissions before the introduction of videophones. Twenty of 30 videophone calls from the same patients were of clinical significance after the installation of videophones, of which only 7 ended in unscheduled visits or admissions. It is thus conceivable that a videophone can be considered capable of decreasing by 77% the number of unscheduled hospital visits or admissions. This was not possible with regular telephone calls.
There are several limitations of this study. One is the before-and-after comparison nature of this study. Exactly the same patients and families were involved in this with- and without-videophone comparison (group I). This cannot be considered a controlled study. The duration of each study period did not extend for a full four seasons. The switchovers to the videophones did take place during the summer months (July, August, and September), and both periods included a few winter months. A decrease in unscheduled hospital visits after the videophone system implementation could still be argued as coincidental or seasonal. We did not think this was the case, judging from feedback from families and the magnitude of the decrease. Although unscheduled hospital visits dramatically decreased, the substantial reduction in hospitalization from 22 to 10 days was statistically not significant. Similar to the reluctance families have to call physicians, the families of patients receiving home care have a strong determination to avoid hospital admissions. This and the relatively short study duration may account for the weak effect videophones had on decreasing hospitalization. The potential capability of videophones in handling seizures and worrisome fevers may produce a future reduction in days of hospitalization.

Another limitation is that we could only study the initial 6-month period of videophone introduction, when situations were changing and learning effects were taking place. In fact, the decline observed in the number of phone calls after 3 months in group II indicated this effect. It, however, does not affect the meaning of this study, indicating the potentially beneficial effects, especially during the introduction of home care.

Last, this study took place in Japan in a very small and specific environment, pediatric home respiratory care. Although cost configurations may differ in different health care systems, the effective use of specialists and improvement in quality of life for patients should be universal concerns. The ISDN 64 designated videophone we used was basically developed for home use, unlike other more sophisticated systems being used in telemedicine aiming at higher-quality data transmission. The cost of the hardware should fall rapidly, once its usefulness is recognized by the medical community. The number of cases involved in this study was small, but we thought that it was important to encourage the establishment of a designated home care system.

In summary, the videophone system using ISDN 64 can now be considered a practical and effective tool to use specialist resources more effectively in home care, extending national borders and time zones and improving the quality of pediatric home ventilatory care. The establishment of a designated home care support system using this system is warranted.

ACKNOWLEDGMENTS
We thank Dr. Thomas G. Keens of the Children`s Hospital of Los Angeles for cooperation and encouragement in the international videophone project and Hideo Nakazawa for technical cooperation.

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Interactive Communication in High-technology Home Care: Videophones for Pediatric Ventilatory Care

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