TELEMEDICINE AND REMOTE MONITORING: SUPPORTING THE PATIENT ON PERITONEAL DIALYSIS

Telemedicine is the use of communication technology that may include a broad array of visual and audio platforms to allow the delivery of medical care at a distance from the healthcare provider. One of its goals and its greatest promise is the ability to deliver high-quality, affordable care to those individuals who, due to great distances or for other reasons, would not normally have access to such benefits (1). Such technology permits 2-way communication between the patient and medical staff over long distances with high fidelity and also allows the transmission of complex data such as medical records, images, audio, videos, and physical examination findings through devices such as electronic stethoscopes, ophthalmoscopes, and others. Over the last few decades, telemedicine platforms have become more widespread, and they now enable high-quality, cost-effective care in areas as diverse as cardiology, neurology, ophthalmology, dermatology, psychiatry, emergency medicine, etc. (2).

This review describes telemedicine platforms used to support home dialysis therapies, specifically peritoneal dialysis (PD), which can support patients living in remote areas and help them maintain a good level of independence while ensuring good outcomes. As we have already learned from previous literature, PD has also been shown to be more affordable than hemodialysis (HD) in most parts of the world (3), especially in more developed countries like the USA and in European countries where HD is commonly reported to be 1.40 – 1.50 times the cost of PD. However, despite these advantages, PD is still quite underutilized. Published literature has indicated that lack of frequent nursing support, as there is in HD, less frequent interactions with the nephrologist, and lower levels of clinical oversight with PD than for in-center HD could be possible reasons for PD underutilization (4,5). We strongly believe that a well-designed telemedicine platform can help address these ‘therapy gaps’ by providing an improved level of ‘virtual’ support with embedded educational content that continually enforces proper technique. We speculate that such additions to a PD program can possibly lead to higher patient satisfaction, better comfort and, eventually, higher levels of acceptance of PD as a preferred form of renal replacement therapy (RRT). In fact, a few studies have already demonstrated that PD patients are willing to adopt such technology, with the belief that it could help simplify the therapy (6).

BACKGROUND

AN IDEAL TELEMEDICINE PLATFORM FOR PD

An ideal telemedicine platform focused on PD would have several characteristics (Tables 1 and 2) (7). Firstly, the system

would have the capability to have 2-way, rapid, real-time communication to help troubleshoot problems. This would be supplemented by the capability to regularly provide detailed assessments that allow the patient to remain at home, reducing the frequency of in-person visits to a PD center. The system would have the capability to monitor treatments when necessary as well as maintain compliance with PD prescription. The system should have the capability to capture treatment data through automated collection of therapy variables and the ability to analyze this data. An important, ‘value-added’ feature would be the ability to periodically provide educational content to retrain patients to perform optimal technique. Finally, the system would have the capability to improve outcomes such as peritonitis and exit-site infection rates, volume and blood pressure control, and decrease hospital admissions. By providing these functions, a telemedicine platform would allow for greater patient independence while instilling a

TABLE 1
Ideal Requirements for Telemedicine Monitoring of PD

- Allow user flexibility in movement and activities
- Two-way communications with high-definition video or image capture
- Simple and intuitive alarm systems with a high degree of specificity
- Modifiable and customizable (i.e. monitoring capability at the beginning of training and for first few months may need to be more intensive and then scaled back)
- Generate useful reports
- Non-intrusive and portable

PD = peritoneal dialysis.

TABLE 2
Parameters of PD Exchanges to be Monitored

- Fill and drain volumes
- Fill and drain times
- Blood pressure
- Pulse
- Oxygen saturation
- Weight or bioimpedance
- Time/duration of treatment dwell
- Number of exchanges
- Prescription of dialysis
- Symptoms during therapy
- Alarms and patient response to alarms
- Activity during the day

PD = peritoneal dialysis.

greater degree of confidence that well-trained professionals are closely monitoring the therapy and are readily available for assistance. We would like to emphasize that such systems may demonstrate clinical benefits even if they are merely able to increase patient satisfaction and willingness to use home therapies with significant gain in therapy outcomes.

Candidate platforms have been reported in clinical practice but are limited in their data-capture ability and 2-way communication (8). A recent system described by Berman and colleagues applied to high-risk dialysis patients included remote monitoring of blood pressure, weight, blood glucose, and pulse oximetry along with video capability that transmitted to a central location (9). In this system, scheduled videoconferencing could occur, which was especially useful for patients in remote areas. In this pilot study, the investigators were able to demonstrate that utilization of this technology led to fewer hospitalizations and emergency room visits and lower health-care expenditures. Currently, there are several commercially available systems designed specifically for PD. Although these systems have demonstrated considerable utility, they largely limit their focus to details of PD exchanges (volumes, timing, and alarms) and unfortunately do not incorporate any patient-specific factors or include real-time monitoring and video capture. Additionally it should be noted that most of these systems are only available embedded within cyclor technology.

INTEGRATING TELEMEDICINE INTO CARE PARADIGMS

Telemedicine systems could ideally be included in the holistic care plan for the patient that would include home and clinic visits by the healthcare team. The theme of all PD home and clinic visit protocols would be to adequately complement the telemedicine program with the required follow-up on each individual patient and to identify incorrect practices early, before they become a serious problem. This can have a strong positive impact on PD technique survival, which may eventually lead to significant cost savings. Home-visit protocols are unique to and different in various PD programs. In India, home-visit schedules are prepared by the nephrology team and can be based upon medical needs and conducted by the clinical coordinators (CCs – equivalent to PD nurses). The CCs conduct a step-by-step assessment of patient well-being, monitor an exchange being performed by the patient or by the patient's primary caregiver, perform a thorough check of the PD logbook/tablet application, review the most recent laboratory tests with the patients and their caregivers, and are required to detect any condition that might require the attention of the nephrologist. They also check for exit-site infections and signs of pedal edema and examine the effluent bag for signs of peritonitis. Additionally, the CC also counsels the patient about their nutrition status, psychological well-being, physical fitness, and rehabilitation levels after they finish their complete standardized assessment using SF-36 (Rand Health, Santa Monica, CA, USA) forms. After successful completion of the home visit, the CC enters all the details into the referral PD unit (RPU) records using tablet computers (4). A recent study

conducted by San Bortolo Hospital, Vicenza, described the practice of home visits in Italy. A thorough evaluation of a wide range of elements (i.e. environment, procedure, compliance) was coupled with personalized assistance to each individual patient. This helps each patient learn at a comfortable pace and reinforces proper technique. In addition, a telemedicine application (developed in Italy) was used to collect data about catheter exit site, compliance with dialysis prescription, body weight, blood pressure, and compliance with medication prescription on a regular basis (10).

In the US, the vast majority of patients are seen within a central PD clinic on a monthly basis, with supplemental home visits, usually from the nursing team. In this model, the goal of telemedicine would be to support the patient between clinic visits. Ideally, regulatory bodies would recognize telemedicine and remote monitoring as a valid surrogate for 'face-to-face' visits and thus further the independence of PD patients.

TELEMEDICINE SYSTEMS REPORTED IN PUBLISHED LITERATURE

A study by Gallar *et al.* describes the use of telemedicine in the long-term control of stable patients undergoing PD at home (11). It described a system which made use of videoconferencing equipment installed in each patient's home and connected to a videoconferencing unit at the hospital by 3 integrated services for digital network (ISDN) lines. Another article by Nakamoto described a fully automatic system known as an 'I-converter' which was used to collect and send data via cellular telephone. Later, the team upgraded the system to a newer version called the D-converter which used a 'Personal Handy-phone System (PHS)' and a 'Dopa card' (8). These devices were described as having several advantages including high-speed data transmission, low power output, little electromagnetic interference with medical devices, and easy locating of patients. Struijk reviewed a typical remote monitoring system that made use of multiple cameras including a document scanner, video-conferencing software on a personal computer, an LCD monitor, integrated medical records, all connected via wireless internet (12). He also mentioned the use of mobile applications to receive, record, and store patient data to construct a good electronic medical records (EMR) database. He also briefly described how 'e-consultations' can be very useful in managing remote patients. Schachter *et al.* described an interesting concept of virtual wards (VW). They described VW as a new model of integrated care that provides services to patients who are not physically admitted to hospital, based on a model that would capitalize on the infrastructure built for running a home dialysis program (PD and home HD). They envisaged VW to function as a pro-active, systematic management tool for vulnerable patients and also hypothesized that its implementation would mitigate gaps in care (13).

INITIAL EXPERIENCE WITH TELEMEDICINE IN INDIA, ITALY AND THE USA

A tablet computer (iOS; Apple Inc., Cupertino, CA, USA) application for the purpose of making PD more accessible and

to serve as an interactive user guide to support patients was recently developed by Nayak *et al.* (4,14). The earliest version of this software was first used in 2006 and had immediate benefits for PD patients residing more than 1,000 miles away from the mother PD unit (MPU). Simple image transfers via email allowed the PD unit to diagnose and provide proper care. Figure 1 depicts the schematic of the overall flow of information across the system.

The current version of the software makes use of audio-visual depictions to show patients what to do at every step of a PD exchange. It is also capable of training patients before PD initiation and requires only a total of 4 hours' training (i.e. 4 1-hour sessions spread over 4 days). This software can also potentially reduce training time as well as periodically reinforce optimal technique. In addition to recording details about the PD exchange (time, volume, percentage of dextrose, and other variables), this software is also capable of recording videos and taking images. All recorded information is automatically updated on a web-based system database that resides at the PD center and viewed in real-time. The web-based system also allows real-time interaction between patients and primary healthcare providers through online chats. This chat feature enables patients to use their tablet computer to discuss any other medical issue via the online system, which is visible only to the nephrologist and the CCs.

The care team can use the web-based system to make prescription changes, diagnose PD-related problems, and provide dietary advice, or make any extra comments as required. Since there is a plethora of sensitive patient information, this database is secured, protected, and is only accessible to the nephrologist and responsible PD nurses. The ultimate goal of the system is to help facilitate early diagnosis and resolution of exit-site infections, peritonitis, and fluid status, easily monitored by sequential pedal edema images on the software, possibly leading to important long-term reduction in left ventricular hypertrophy and attendant cardiac morbidities and any other complications such as ultrafiltration failure that might lead to hospitalization if undetected. The remote monitoring system keeps caregivers informed about every patient and enables scheduling of an emergency home visit. Figure 2 is a screen shot of the tablet program.

METHOD

INITIAL EXPERIENCE WITH TELEMEDICINE IN INDIA

A total of 246 PD patients, all of whom were enrolled in the earlier telemedicine system in their day-to-day care, were observed and retrospectively analyzed (4). The rural patient is generally considered to have poor outcomes in therapy results for chronic kidney disease (CKD) compared with urban patients, possibly due to lack of immediate access to health-care, and hence we decided to compare the 2 groups and the impact of telemedicine. The patient cohort was divided into a rural group, which included 115 patients, and an urban group, which included 131 patients. Mean follow-up was 4,296

Figure 1 — Software Process Architecture indicating the basic framework of the PD remote monitoring platform. PD = peritoneal dialysis; FL = Florida; NJ = New Jersey.

Figure 2 — Snapshot of tablet software showing various features of the remote monitoring software. Patient details and imagery are stored showing baseline PD effluent bags and exit sites at baseline and 'current.' A zoom tool confirms a 'normal' exit site at left extreme. (Patient consent was obtained for permission to use the image.) PD = peritoneal dialysis.

patient-months (2,008 in the rural group, 2,288 in the urban group). The final results showed similar technique survival rates, similar peritonitis rates, and similar exit-site infection rates in both groups throughout the study period. The rural patient group performed well on PD and had significantly better 5-year survival rates than did their urban counterparts, despite reduced proximity to the PD center.

Another study was designed to track quality of life and socioeconomic-related parameters of tele-monitored patients who performed PD in both urban and rural settings. This study also featured a comparison between PD patients and regular in-center HD patients under the care of the same nephrology center. Analysis of the results revealed no significant difference between rural and urban patients in terms of quality of life. It also demonstrated that rural patients had a significantly reduced number of visits to the hospital, fewer hospitalized days, and fewer nephrologist consultations, which contributed to an overall reduced cost of therapy (14). Future research is

likely to demonstrate that implementation of such systems is accompanied by favorable clinical and socioeconomic outcomes in PD patients.

INITIAL EXPERIENCE WITH TELEMEDICINE IN ITALY

A recent Italian study conducted at the San Bortolo Hospital, Vicenza, described the implementation of a telemedicine program supported by a home-visit program. After 1 year of observation, the authors reported a significant reduction in technique failure in the case group. Although the study reported no statistically significant difference in terms of peritonitis and hospitalization rates, there was a trend toward reduction of gram-positive peritonitis rates and hospitalizations related to PD problems. Such a program may provide the opportunity to improve the quality of care and 'humanize' RRT, as well as reduce treatment costs (10).

INITIAL EXPERIENCE WITH TELEMEDICINE IN THE USA

Subsequently, a revised version of the PD remote monitoring software developed by Nayak and colleagues underwent a pilot analysis at the University of Virginia Health System (15).

Six continuous ambulatory PD (CAPD) patients were enrolled in the first pilot study performed in the USA. A total of 1,172 exchanges were recorded over a period of 251 days. Compliance with the applications ranged from 51 to 92%. No major adverse events were recorded. The study was able to prove that a tablet computer platform is a feasible concept for PD. The initial patient response to various components of such a system allowed the caregivers to assess what features were most beneficial. These included flexibility, 2-way communication, and real-time interaction and suggested that such software might increase the acceptability of PD as the preferred modality of therapy for ESRD.

DISCUSSION AND SUMMARY

From the showcased experiences, the potential benefits of a well-structured telemedicine protocol for PD can allow for the assessment of the patient's home environment, adherence to the prescribed technique, observation, and correction of potential or real hazards that may increase risk of infection, and reinforcement of patient confidence in self-care by providing support and encouragement. Furthermore, home-visit programs coupled with telemedicine surveillance encourage a closer relationship between the patient and their caregivers. We already know from recently published literature that remote monitoring coupled with strong follow-up has been able to make a significant positive impact on patients with pacemakers and implantable cardioverter defibrillators in terms of fewer in-clinic visits, higher patient satisfaction, and considerable cost savings (16,17,18).

Although we do not have such in-depth evidence at present, we know that telemedicine in PD shows great promise.

The study by Gallar *et al.* went on to demonstrate a significant reduction in the yearly hospitalization rate during a 2-year follow-up period (11). A much earlier short report by Cargill and Watson spoke about the use of a similar setup involving an ISDN 2E line for the transmission of images. Even though the study was conducted at a time when such technology was only available at a prohibitive cost, they were able to show that such a system could be useful for pediatric PD patients (19). Nakamoto and team created a telemedicine system which they feel would be useful especially for elderly and handicapped patients on PD (8). An article from Norway by Rygh *et al.* concluded that telemedicine may potentially facilitate a communication-based follow-up and improve safety within the home setting, making it easier to choose and live with home dialysis (5).

Telemedicine, once widely used, with a high load of patients and their data maintenance, might suffer from high maintenance and service expenses, severe capability limitations, lack of experienced professionals, and interoperability issues. This should not deter us from embracing the technology, as the long-term benefits far outweigh these problems, which we will learn to address, in a stepwise manner. Most patients in the 2 studies from India and the USA wanted to continue the telemonitoring of their therapy, showing no novelty attrition (4,15). The current use of telemedicine shows promise in improving outcomes and uptake of PD across the world. However, these results have been reported in single centers, and a broader clinical trial that randomizes a larger number of patients to a telemedicine intervention is definitely needed. With larger trials, more substantive data on clinical and economic outcomes may be derived. However, what is currently clear is that the technology is available and may become part of standard PD care, if proved effective.

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