In the present study, we investigated longitudinal changes in peritoneal function, as calculated by the personal dialysis capacity (PDC) test, after patient withdrawal from 17 years of continuous ambulatory peritoneal dialysis (CAPD).

In July 1982, a 42-year-old female was started on CAPD because of chronic renal failure. She performed CAPD without any trouble for 17 years. In July 1999, hemodialysis was introduced because of ultrafiltration failure. The CAPD catheter remained in place, and the patient subsequently performed intra-abdominal lavage, using a standard peritoneal dialysis (PD) solution, for 3 years. A PDC test was performed every 6 months before and after withdrawal from CAPD. In July 1999, the PDC test indicated a membrane area of 59,748 cm/1.73 m², absorption of 2.72 mL/min/1.73 m², plasma loss of 0.049 mL/min/1.73 m², and ultrafiltration volume (UFV) of –666 mL/24 h. The dialysate-to-plasma ratio (D/P) of creatinine after 4 hours was 0.96. An abdominal computed tomography (CT) scan showed calcification of the peritoneum. In March 2000, the PDC showed an area of 44,929 cm/1.73 m², absorption of 1.43 mL/min/1.73 m², plasma loss of 0.092 mL/min/1.73 m², and a UFV of 213 mL/24 h. In August 2000 (1 year after CAPD withdrawal), the area was 38,492 cm/1.73 m²; the absorption, 1.74 mL/min/1.73 m²; the plasma loss, 0.053 mL/min/1.73 m²; and the UFV, 348 mL/24 h. Long-term intra-abdominal lavage induced a gradual reduction in membrane area, which returned to the normal range (19,028 cm/1.73 m²) after 3 years. Ultrafiltration volume showed a gradual increase and reached its peak level (403 mL/24 h) in July 2002. After 3 years, the D/P creatinine was 0.82. However, an abdominal CT scan showed no change in the calcification of the peritoneum.

From those data, we conclude that, in long-term CAPD patients, intra-abdominal lavage can induce improvement in peritoneal function, but not in calcification of the peritoneum.

Key words
Long-term CAPD, personal dialysis capacity test, peritoneal function, intra-abdominal lavage

Introduction
Long-term continuous ambulatory peritoneal dialysis (CAPD) treatment has been determined to be a risk factor for high peritoneal permeability and development of encapsulating peritoneal sclerosis (EPS) (1). To reduce the risk of EPS after withdrawal from CAPD, trials have been performed of protective measures such as intra-abdominal lavage (2), glucocorticoid treatment (3,4), and immunosuppressive drugs (2), among others. However, the protective effects of those treatments remain uncertain.

In 1992, Rippe (5) introduced the three-pore model of the peritoneal membrane for solute transport. Based on that concept, Haraldsson (6) developed a computer program for analyzing peritoneal...
function and termed it the personal dialysis capacity (PDC) test. The PDC test has been used to obtain digital data about peritoneal function for serial analysis of individual patients and for mass analysis of groups of patients. The PDC computer program (Gambro Lundia AB, Lund, Sweden) calculates the physiologic state of the peritoneum in terms of three parameters: membrane area, absorption, and plasma loss (6). A few reports regarding clinical application of the PDC test have appeared in the literature (7,8); however, no previous studies have compared their results with data on peritoneal function obtained using the PDC test in mass studies of CAPD.

In our practice, we had a patient who had been on long-term CAPD (17 years). After the patient was withdrawn from CAPD, the peritoneal catheter remained in place, and the patient performed intra-abdominal lavage using a standard peritoneal dialysis (PD) solution for the subsequent 3 years. In that long-term CAPD patient, we investigated the effect of the intra-abdominal lavage on peritoneal function by performing the PDC test every 6 months for 3 years after withdrawal of CAPD.

Protocol of the PDC test
The PDC program version 3.1 was provided by the Gambro–Shimizu Pharmaceutical Company and was used according to the manual by Haraldsson (6). Laboratory data were entered for each dialysis condition (Baxter Healthcare, Toyko, Japan).

Albumin in dialysate was measured using an assay for microalbumin. The dialysate concentration of microalbumin was measured by a latex agglutination system (9).

The presentation of the PDC data was standardized to the use of 8 L of 2.5% glucose solution (2.27 g/dL glucose) daily. Because the data from the PDC test changes under various dialysis conditions, those data could be analyzed by serial study in individual patients and by group analysis in group studies. Preliminary studies revealed that a dialysate glucose concentration of 2.27 g/dL is more appropriate for serial analyses of peritoneal function than is a 1.36 g/dL glucose solution, because many patients extract insufficient water via the peritoneum (<1000 mL daily) using 1.36 g/dL glucose. Some patients even extracted <500 mL/day.

Results
Average PDC data for non diabetic CAPD patients in Japan
To clarify the average data from the PDC test, we performed a multicenter prospective study in Japan. The PDC test was performed in 240 informed, non diabetic patients (134 men, 106 women) of median age 46 years (range: 8 – 83 years) who were attending the renal dialysis unit. Table I shows the average PDC data in those patients, including area [cm/1.73 m² body surface area (BSA)], absorption rate (mL/min/1.73 m²), and large-pore flow [plasma loss rate (mL/min/1.73 m² BSA)].

Case report
In July 1982, a 42-year-old woman was started on CAPD because of chronic renal failure. She performed CAPD without any trouble for 17 years. In July 1999, hemodialysis was introduced because of ultrafiltration failure. The CAPD catheter was left in place. The woman performed intra-abdominal lavage using a standard PD solution [1 L, pH 4.5 – 5.5, 1.36% glucose (PD-4: Baxter Healthcare)] for 3 years after withdrawal of CAPD. The patient was instructed to exchange a solution bag once daily.

Table I: Personal dialysis capacity (PDC) parameters (mean ± standard deviation) in patients without diabetes mellitus undergoing continuous ambulatory peritoneal dialysis

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Mean ± Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Membrane area (cm/1.73 m²)</td>
<td>21,860±9,817</td>
</tr>
<tr>
<td>Absorption (mL/min/1.73 m²)</td>
<td>1.40±0.72</td>
</tr>
<tr>
<td>Plasma loss (mL/min/1.73 m²)</td>
<td>0.09±0.05</td>
</tr>
<tr>
<td>Water permeability (mL/min/mmHg/1.73 m²)</td>
<td>0.069±0.027</td>
</tr>
<tr>
<td>Peritoneal UF (mL/24 h)</td>
<td>1.45±1.74</td>
</tr>
<tr>
<td>Urine volume (mL/24 h)</td>
<td>223.9±346.8</td>
</tr>
<tr>
<td>Total UF (mL/24 h)</td>
<td>1,674.4±808.4</td>
</tr>
<tr>
<td>Peritoneal CCr (mL/min/1.73 m²)</td>
<td>5.60±0.99</td>
</tr>
<tr>
<td>Residual renal function (mL/min/1.73 m²)</td>
<td>0.89±1.49</td>
</tr>
<tr>
<td>Total CCr (mL/min/1.73 m²)</td>
<td>6.50±1.60</td>
</tr>
<tr>
<td>Kt/V urea</td>
<td>2.168±0.592</td>
</tr>
<tr>
<td>Protein loss from PD (g/24 h)</td>
<td>6.4±2.9</td>
</tr>
<tr>
<td>Dietary protein intake (g/24 h)</td>
<td>53.3±9.3</td>
</tr>
<tr>
<td>Calories from PD (kcal/24 h)</td>
<td>426.4±85.7</td>
</tr>
<tr>
<td>Dietary calorie intake (kcal/24 h)</td>
<td>1,377.3±297.7</td>
</tr>
<tr>
<td>Urea generation rate</td>
<td>0.12±0.05</td>
</tr>
<tr>
<td>Creatinine generation rate</td>
<td>5.81±2.07</td>
</tr>
<tr>
<td>PNA/PCR (g/kg/24 h)</td>
<td>1.16±0.36</td>
</tr>
</tbody>
</table>

UF = ultrafiltration; CCr = creatinine clearance; PD = peritoneal dialysis; PNA = protein nitrogen appearance; PCR = protein catabolic rate.
We performed a PDC test to check peritoneal function before withdrawal of CAPD. Table II shows the data from that test (July 1999). As calculated by the PDC program, the membrane area was 59,748 cm/1.73 m²; absorption was 2.72 mL/min/1.73 m²; plasma loss was 0.049 mL/min/1.73 m²; and ultrafiltration volume (UFV) was –666 mL/24 h. The dialysate-to-plasma ratio (D/P) of creatinine after 4 hours was 0.96. An abdominal computed tomography (CT) scan showed calcification of the peritoneum.

The PDC test was repeated every 6 months after withdrawal of CAPD. Figures 1 and 2 show the changes in area and UFV as calculated by the PDC program. In March 2000, the area was 44,929 cm/1.73 m²; the absorption, 1.43 mL/min/1.73 m²; the plasma loss, 0.092 mL/min/1.73 m²; and the UFV, 213 mL/24 h. In August 2000, the area was 38,492 cm/1.73 m²; the absorption, 1.74 mL/min/1.73 m²; the plasma loss, 0.053 mL/min/1.73 m²; and the UFV, 348 mL/24 h. Long-term intra-abdominal lavage induced a gradual reduction of membrane area, which returned to the normal range (19,028 cm/1.73 m²) after 3 years. The UFV showed a gradual increase, reaching its peak level of 403 mL/24 h in July 2002.

Figure 3 shows the changes in D/P creatinine. The D/P creatinine after 3 years was 0.82. However, an abdominal CT scan showed no change in peritoneal calcification.

### Table II

Results of personal dialysis capacity (PDC) test in a 59-year-old woman after 17 years of continuous ambulatory peritoneal dialysis

<table>
<thead>
<tr>
<th>Membrane area (cm/1.73 m²)</th>
<th>59,748</th>
</tr>
</thead>
<tbody>
<tr>
<td>Absorption (mL/min/1.73 m²)</td>
<td>2.72</td>
</tr>
<tr>
<td>Plasma loss (mL/min/1.73 m²)</td>
<td>0.49</td>
</tr>
<tr>
<td>Water permeability (mL/min/mmHg/1.73 m²)</td>
<td>0.077</td>
</tr>
<tr>
<td>Peritoneal UF (mL/24 h)</td>
<td>–666</td>
</tr>
<tr>
<td>Urine volume (mL/24 h)</td>
<td>0</td>
</tr>
<tr>
<td>Total UF (mL/24 h)</td>
<td>–666</td>
</tr>
<tr>
<td>Peritoneal Cr (mL/min/1.73 m²)</td>
<td>6.8</td>
</tr>
<tr>
<td>Residual renal function (mL/min/1.73 m²)</td>
<td>0</td>
</tr>
<tr>
<td>Total Cr (mL/min/1.73 m²)</td>
<td>6.8</td>
</tr>
<tr>
<td>Kt/V urea</td>
<td>2.214</td>
</tr>
<tr>
<td>Protein loss from PD (g/24 h)</td>
<td>3.1</td>
</tr>
<tr>
<td>Dietary protein intake (g/24 h)</td>
<td>38</td>
</tr>
<tr>
<td>Calories from PD (kcal/24 h)</td>
<td>633</td>
</tr>
<tr>
<td>Dietary calorie intake (kcal/24 h)</td>
<td>768</td>
</tr>
<tr>
<td>Urea generation rate</td>
<td>0.0385</td>
</tr>
<tr>
<td>Creatinine generation rate</td>
<td>2.9647</td>
</tr>
<tr>
<td>PNA/PCR (g/kg/24 h)</td>
<td>0.7257</td>
</tr>
</tbody>
</table>

UF = ultrafiltration; CCr = creatinine clearance; PD = peritoneal dialysis; PNA = protein nitrogen appearance; PCR = protein catabolic rate.

### Discussion

After 17 years of CAPD, the membrane area measured in this patient was extremely high as compared with the average area measured by PDC in Japan. Her area measurement (59,748 cm/1.73 m²) was the highest
found among the data from 385 PDC tests in Japan. Her D/P creatinine after 4 hours of a peritoneal equilibration test was 0.96.

Those data demonstrate extremely high peritoneal permeability after long-term CAPD. We were very worried that this woman would develop EPS. To prevent EPS, we left her CAPD catheter in place and had her use standard PD solution to perform daily intra-abdominal lavage.

Long-term intra-abdominal lavage induced a gradual reduction in membrane area, which returned to the normal range after 3 years. Ultrafiltration volume showed a gradual increase, and, after 3 years, the woman’s D/P creatinine was 0.82. The woman was in good condition undergoing maintenance hemodialysis. There were no signs of EPS. From those data, we conclude that, in long-term CAPD patients, intra-abdominal lavage can be effective in repairing peritoneal damage and inducing improvement in peritoneal function.

Encapsulating peritoneal sclerosis is one of the most serious complications in patients on CAPD or intermittent peritoneal dialysis (IPD). It is characterized by partial or intermittent bowel obstruction accompanied by marked sclerotic thickening of the peritoneal membrane (10–12). Gandhi et al. (1) first reported the complication in 1980. Those authors described the appearance of marked sclerotic thickening of the peritoneal membrane in 5 patients on IPD. Recently, many cases have been reported (12–15), but little is known about the earliest identifiable abnormalities that might allow a diagnosis to be made before symptoms develop. Cases of EPS seem to be especially frequent in Japan. In 75% cases, the condition has been reported to develop after CAPD termination and catheter removal. Intestinal adhesions progress owing to the absence of dialysate after PD discontinuation. The inflammatory reaction is also accelerated.

In a previous study, various inflammatory substances released from the injured peritoneum were reported to induce progressive fibrosis and sclerosis of peritoneum, resulting in intestinal adhesions (16). Intra-abdominal lavage was effective at eliminating possible inflammatory factors from the abdominal cavity, thereby helping to prevent the development and progression of EPS after withdrawal from CAPD. In addition, PD solution may act as a buffer for the intestine.

Recently, Moriishi et al. (17) reported that intra-abdominal lavage through the peritoneal catheter preserved after PD withdrawal enhances the recovery of peritoneal damage. Those authors followed changes in the appearance rate (AR) of cancer antigen 125 (CA125) in dialysate as a marker of peritoneal mesothelial mass and changes in D/P creatinine as a marker of peritoneal function. The CA125AR increased and the D/P creatinine decreased. The appearance rate of CA125 seemed to be a good marker of viability and proliferation of mesothelial cells. However, those authors reported that, in some cases, peritoneal injury did not improve and EPS developed despite the measured increases in CA125AR. Based on those results, a new marker of peritoneal damage needs to be established for such intractable cases.

Peritoneal membrane characteristics can be evaluated by several methods. The method most often used worldwide is the PET. Twardowski et al. (18) developed the PET in 1987 to monitor adequacy of the peritoneum as a dialytic membrane. The test was designed to determine the membrane transport characteristics of CAPD patients. Major reasons for the widespread use of the PET are the standardization of the procedure and the simplicity of the calculations (19,20). Twardowski and colleagues (18) observed that patients with transport rates more than one standard deviation from the mean were unlikely to remain on standard
CAPD after 20 months of treatment. The PET provides support for routine measurement of those parameters as markers of delivered dialysis adequacy in stable CAPD patients.

Although the PET provides information about the dialyzing characteristics of the peritoneum, it yields little further prognostic information concerning the patient. In 1995, Haraldsson (6) developed a computer program for analyzing peritoneal function according to the three-pore model of Rippe (5) and named it the personal dialysis capacity (PDC) test. In 1996, Vonesh et al. (21) developed another analysis program named PD Adequest. The PDC test and PD Adequest have both been used to provide digital data concerning peritoneal function for serial and mass analysis of CAPD patients. The useful features of the PDC test are convenience of data entry during routine dialysis (with two blood samples in 24 hours), abundant results regarding peritoneal function and diet, easy recommendation of dialysis treatment for each patient, and accurate comparisons of the digitized data points both in the clinical course of individual patients and in mass studies (6,21).

Recently, a few clinical applications of the PDC test have been reported. Imai et al. (7) reported that the PDC test is useful for evaluating changes in peritoneal function on CAPD. Schaefer et al. (22) reported that the PDC test permitted modeling of peritoneal solute and water transport with remarkable precision in children of all age groups.

In the present study, we followed peritoneal function data calculated by PDC test in a patient every 6 months before and after withdrawal from CAPD. We were able to evaluate changes in peritoneal function after PD withdrawal. Improvement in peritoneal permeability was observed with 2 years of intra-abdominal lavage. However, peritoneal calcification did not improve even after 3 years of intra-abdominal lavage.

Peritoneal calcification is well known as a serious risk factor for EPS. We have therefore recommended continuation of intra-abdominal lavage in the case reported here. We have no criteria on which to base discontinuation of intra-abdominal lavage. More studies will be required to establish such criteria.

Conclusions
In long term CAPD patients, intra-abdominal lavage is effective at repairing peritoneal damage and inducing the improvement of peritoneal function, but not at improving calcification of the peritoneum.

References


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Our objective in the present study was to evaluate the dialysis dose required to maintain Japanese peritoneal dialysis (PD) patients in good condition. From 32 local hospitals, we selected 100 stable patients without diabetes mellitus who were on continuous ambulatory peritoneal dialysis (CAPD) or automated peritoneal dialysis (APD), and we performed the peritoneal function test using the newly developed PD NAVI software (JMS, Hiroshima, Japan). Weekly total $Kt/V$ and creatinine clearance ($CCr$) were calculated and plotted against body weight (BW) to evaluate the PD dose. In CAPD patients ($n = 58$), we found an inverse linear correlation between total $Kt/V$ and BW ($r = -0.576$). In the same patients, total $Kt$ remained essentially constant (60 L/week). Those results imply that most patients were being treated with the same PD regimen (2 L, 4 times daily), and that smaller patients were generally receiving a greater PD dose relative to body size than were the larger patients. In APD patients ($n = 21$), total $Kt/V$ and total $CCr$ normalized to 1.73 m² did not change with BW. Total $Kt$ and non-normalized $CCr$ gradually increased with BW, although the correlation was not significant. Those findings suggest that most APD patients received prescriptions that were more closely based on body size. In conclusion, smaller patients generally receive a greater PD dose than do larger patients, and targeting a single value of $Kt/V$ or $CCr$ may not always be relevant for adequate dialysis.

Key words
$Kt/V$, creatinine clearance, PD dose, CANUSA study, NKF–DOQI guidelines
In CAPD patients \((n = 58)\), we found an inverse linear correlation between weekly total Kt/V and BW (correlation coefficient: \(r = -0.576\); Figure 1). At the same time, total Kt remained essentially constant at 60 L/week (Figure 2). Those results imply that most CAPD patients are treated with the same regimen (2 L, 4 times daily) regardless of body size. As a result, smaller patients are generally receiving a greater dose of dialysis relative to body size than are larger patients.

In APD patients \((n = 21)\), weekly total Kt/V was almost constant at 1.7 (Figure 3), and total CCr normalized to 1.73 m\(^2\) did not vary with BW (Figure 4). Total Kt and CCr (not normalized to 1.73 m\(^2\)) gradually increased with BW, although the correlations were
not significant (Figures 5 and 6). Those findings suggest that most APD patients received prescriptions that were more closely linked to body size.

Based on our results, CAPD patients with a relatively small body size appear to receive a greater PD dose than do patients with a relatively large body size. The dose given to APD patients appears to be more carefully chosen, with consideration for the patient’s body size. Generally speaking, Asian PD patients are relatively smaller than Caucasian PD patients. Asian CAPD patients do not necessarily meet recommended values of Kt/V or CCr (6). In Hong Kong, for example, CAPD patients are usually treated with a regimen of 2 L three times daily and excellent clinical results are still reported (6). Those good results may be due to the fact that an adequate dose can be non-linearly calculated to a patient’s body size.

Conclusions
Small CAPD patients (such as Asian patients) are generally treated with a greater PD dose relative to body size than are larger patients. Small patients may not necessarily have to meet recommended Kt/V or CCr values to receive adequate dialysis.

References

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Strategic planning for chronic dialysis services to allow cost-effective organization of resources and workforce planning is a difficult but essential task. The planning process within an individual unit involves consideration of both generic issues and issues specific to the unit. We used the Balance of Care approach to planning, which takes into account the affect that the dependency level of patients has on the therapeutic options and on how those options can be delivered. In a workshop format, we developed a spreadsheet computer model (RENPLAN) and applied it to facilitate discussion between clinical and non clinical health care professionals, dialysis unit managers, and renal patient representatives. Within the unit concerned, we used the model to explore a variety of planning options, including reducing the number of patients receiving automated peritoneal dialysis (proposed as a cost-reduction measure by managers). The model precisely calculates future resource requirements (staff numbers, hemodialysis stations, disposables costs), indicates deficits in clinical audit data, and facilitates education of non clinical managers regarding the major issues in dialysis planning. The RENPLAN model is freely available to all units and is adaptable for analysis of local planning issues.

Key words
Planning, resources, costs

Introduction
The strategic planning of chronic renal dialysis services is essential (given their high cost) and difficult [given the potentially wide variety of appropriate services—methods of hemodialysis (HD) delivery, peritoneal dialysis (PD) techniques—and of resources required for management of dialysis patients]. A large proportion of the cost of dialysis is indirect (1) and difficult to examine in detail.

Overall, the cost of dialysis is substantial: in the United States, $15.6 billion is spent on the care of patients with end-stage renal failure (2). That cost is likely to rise over the next decade with the increase in the elder population and as patients with significant comorbidity are accepted into chronic dialysis programs (3). Also, important differences are seen in resource use by various groups of patients. The variations are caused both by patient factors and by management issues. An elderly patient with significant comorbidity may use additional resources (transport; nurse, social worker, and dietitian time; inpatient days) as compared with a younger patient without comorbidity (4).

Arora et al. (5) examined the factors associated with the increased cost of care among incident dialysis patients. The presence of ischemic heart disease and peripheral vascular disease significantly and independently increased the cost per patient–year at risk by $13,715 and $15,357 respectively. A change in HD practice that leads to less-adequate dialysis may result in some savings (facility time, nurse time), but is offset by additional costs [inpatient days, dose of erythropoietin (EPO)] and a reduced quality of service (6).

Various computer models have been developed to calculate the potential number of future dialysis patients (7,8), but they yield only the number of patients on dialysis and simple cost estimates. They do not allow for an exploration of the resource implications of various proposed service configurations to provide overall management of the patients.

During the present study, we developed a computer model to calculate resource implications and costs for the strategic planning of renal dialysis services. Our model can be used in individual units, tak-
ing into account local and generic factors and allowing for rapid examination of various approaches.

Methods

The Balance of Care approach

Our project adapted an existing, holistic, “whole systems” strategic planning framework: the Balance of Care (BoC) approach, which has been used successfully in similar service-planning scenarios for other client groups—long-term care for older people and services for people with HIV/AIDS (9,10). The approach is multidisciplinary, comprising a series of workshops that are directly supported by a spreadsheet-based planning model specific to the client group. For a specified planning year, the model calculates volumes and costs of required services according to assumptions about the levels of dependency in the planning population and the “packages of care” offered.

Importantly, the approach brings a needs-led—rather than a service-led—focus to the planning process. The needs-led focus helps to keep discussion about future developments open by preventing the adoption of a narrow perspective dominated by existing service configurations. The workshop contributors are responsible for defining the relevant dependency categories and the appropriate care options and services for the client group. The model then uses that information to enable extensive and fast policy testing that explores the potential resource consequences of given planning objectives under any range of assumptions.

Adaptation of the BoC approach to dialysis planning

Our study examined one U.K. dialysis unit. The unit chose to use two main factors to divide the planning population: patient dependency and distance from the renal unit. Taking as a starting point the six groups defined by the U.K. Renal Association (11), the unit established appropriate patient dependency groups. Distance of a patient’s residence from the renal unit was considered to be important in deciding appropriate dialysis options. The Renal Association and patient groups both regard a traveling time for dialysis of more than 30 minutes (“distant” as opposed to “near”) as unsatisfactory. The six initial dependency groups were doubled to take distance into account.

For each dependency group, a range of potential care options can usually be specified; these options can reflect existing best practice and “ideal” options that may not currently exist locally. Table I shows five potential care options for one dependency group: people 55 – 64 years of age who are not diabetic and who live more than 30 minutes’ travel time from the renal unit. The care options are read vertically. They represent an “ideal” average package of care per person over a 1-year period. Each service item is costed according to its particular characteristics and is adjusted by an appropriate conversion factor to annualize the result.

All aspects of the RENPLAN model can be easily changed as required: dependency groups, care options (dialysis modalities), service descriptions, and costs. The outputs of the model are calculations of the resource requirements—for instance, number of HD stations; numbers of nurses, dietitians, and social workers; consumables/drug costs; and number of inpatient beds. The data are presented in a variety of tabular and graphical forms and can be used to examine the effect of change in care options on various organizations providing services or funding or on particular dependency groups or localities within the planning area. It is also possible to define an overall “quality” score for individual care options and to view the planning exercise in terms of the quality of care likely to be produced. Defining the values of the quality index is an interesting exercise in itself, because anyone involved in the process can play a part: physicians, other care professionals, and patients.

Results

Validity of the model

To establish the validity of the model, we populated it with the current dialysis patients of a single U.K. renal unit. All the unit’s health care professionals provided input to establish estimates of staff time for each dependency group. The RENPLAN model successfully and accurately calculated resource requirements (dialysis stations, staff numbers, costs) to dialyze those patients according to current dialysis modality.

Using RENPLAN for strategic dialysis planning

After the validity of the model was established, RENPLAN was used in a local planning workshop with both clinical and non clinical staff to examine possible planning scenarios for the next five years. The major planning problem for this particular renal
unit was how to provide dialysis for a socially deprived inner city area and a large rural population living distant from the dialysis unit. First, future dialysis needs in the catchment population for the target planning year (estimates of the number of future patients requiring either HD or PD) were calculated with an established model widely used in the dialysis planning environment (7). Then, from the unit’s records, patients currently receiving dialysis treatment were classified according to the twelve established dependency groups. The estimate of patient demand for 2003 was then allocated to the dependency groups in the proportions seen among current patients. In a workshop, three planning scenarios related to potential service requirements in 2003 were then explored.

**SCENARIO 1**
Patients would be managed using the three currently available treatments—center HD, continuous ambulatory peritoneal dialysis (CAPD), and automated peritoneal dialysis (APD)—in the same proportions. The scenario would require expansion in HD provision and in both HD and PD nurse numbers. The overall budget would increase (Figure 1: “2003”). This scenario would also require a physical expansion of the center HD unit to provide new stations. There were also other implications (for example, an increased number of inpatient beds).

**SCENARIO 2**
The “Satcom” scenario explored the possibility of developing smaller HD facilities local to the patients. These options were modelled:

- A minimal-care satellite HD unit within an existing hospital facility
- A single-station dialysis unit in each of two community hospitals in rural areas

The service levels (and costs) for the scenario (Figure 1: “Satcom”) showed that either options...
would be feasible and would carry patient benefits in terms of reduced travel time for treatment. The Satcom scenario was also less expensive than scenario 1, because no expansion at the center HD unit would be required, and patient transport costs would be lower.

SCENARIO 3
A third option, proposed by the non clinical managers, explored the impact of substituting cheaper CAPD treatment for APD. The “No APD” scenario was driven by concerns about levels of reimbursement. Under the scenario, no new patients would start APD, and patients would be assigned to CAPD and HD in a 40:60 ratio. The scenario was found to have only a minimal impact on overall costs and a significant adverse resource requirement for additional HD capacity (Figure 1: “No APD”). The quality-factor routine demonstrated that limiting APD and allowing only CAPD or center HD produced a fall in overall quality of the delivered service.

Making the choice
The planning workshop led to these developments:

- A decision was made to maintain funding of APD and to continue to offer that modality as an initial dialysis modality along with HD and CAPD. Agreement with purchasers was reached, and APD remains a popular modality choice. Additional PD nursing staff have been appointed to care for the increased patient numbers.
- On further consideration of plans from two adjacent renal units, it was decided that the satellite unit was not viable in the planned location. Plans are being considered for a community hospital HD unit in one rural area.
- An expansion of the center HD unit was completed with the creation of six further dialysis stations and an initial expansion in the number of dialysis nurses. A negotiated, phased increase in nursing staff is to occur as patient numbers increase. That approach has allowed timely training of nursing staff, recruited at a junior grade.
- The hospital accepted that a physical expansion in the renal unit was needed both for HD stations and PD training areas and for office and general space. The expansion has been completed.

Discussion
The project demonstrates that a relatively simple and effective model can succeed in capturing the main issues involved in strategic dialysis planning and decision making. The model not only enhances the use of existing data, but organizes those data in a way that is directly meaningful for clinicians and managers in setting strategic objectives. The ability to define and to incorporate a quality factor directly into planning discussions acts as a counterbalance to resource-limiting therapy options. For instance, a discussion regarding reducing HD hours to reduce cost could be modelled, but physician input also permits modelling the subsequent adverse effects on quality of care and “indirect” costs such as EPO and inpatient days.

As the CHOICE study showed, ambivalence from non clinical dialysis administrators still exists in the United States regarding the links between reimbursement and adequacy of dialysis or patient outcomes (12). That study demonstrated the conflicting priorities of dialysis administrators and clinical staff, a problem that the RENPLAN approach can help.

Delivery of health care, including dialysis, is performed in a variety of fashions and varies significantly both between and within countries. It is interesting to note the variation in clinical outcomes between countries (13,14) and between providers funded in different ways within the same country (15). All countries share the problems associated with underprovision of facilities contrasted with rising demand for dialysis from an aging population. The RENPLAN model was developed within the U.K. health system and, so far, has been used from the perspective of the provider organization. However, it could be used from the perspective of a “purchaser” or “commissioning” organization.

From the outset, RENPLAN was designed as a generalizable model. It is easily and fully adaptable to specific local planning issues and can be populated in any way appropriate to the needs of the planning population. In addition, RENPLAN can be extended to include renal transplantation, acute renal failure, and general nephrology. Alternatively, RENPLAN can be used to examine in close detail the cost and resource implications of dialysis initiation and the impact of referral patterns.

Our approach does not claim to offer definitive plans or answers to problems, but it does help to structure the uncertainty that inevitably surrounds strate-
Strategic Dialysis Planning Model

gic planning and to indicate where detailed follow-up work might be usefully undertaken. It also offers a framework in which professional groups and organizations involved in the provision and commissioning of care can develop a common language.

The flexibility of the model means that changing data items, care options, and population allocations as required during a planning workshop is simple and that the implications are seen immediately. Scenarios can be compared to existing levels of service or dependency through a series of table and graph displays. Users might start by obtaining an overall impression of the potential impact of a particular scenario and then gradually “zoom in” to see how the scenario affects individual dependency groups, services, or localities within the study area. An iterative cycle of assumption testing can then be undertaken until strategic objectives and constraints have been satisfied.

Conclusion
An established strategic planning tool was adapted for the strategic planning of renal dialysis services. Used in a workshop format, the RENPLAN model allows exploration of the various issues within an individual renal unit or a larger organization and calculation of the future resource and cost implications. The RENPLAN model is available without cost from the authors.

References

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