COMPARISON OF APPARENT EFFICIENCY OF HAEMODIALYSIS SATELLITE UNITS IN ENGLAND AND WALES USING DATA ENVELOPMENT ANALYSIS

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Abstract

Objectives: To expand care for chronic haemodialysis (HD) patients throughout England and Wales by studying two aspects of service delivery that are important: to identify relative performance of haemodialysis satellite units (HDSUs), and understand the factors that influence the performance. As a first step toward these aspects, this work reports a study of apparent comparative efficiency in the delivery of HDSUs and demonstrates the potential of data envelopment analysis (DEA).

Methods: DEA was applied to data obtained from a national survey of the organizational structures and processes of delivering care at HDSUs in England and Wales.

Results: DEA was found to be a judicious approach for performance assessment of HDSUs, although valid results depend on appropriate model specification and quality of data available. The available data were not of sufficient comprehensiveness or quality to produce definitive results but suggested that overall efficiency could improve; these data suggested by as much as 10% overall (mean efficiency score 90%) and variably within the sample (46 [65%] that HDSUs were potentially inefficient, the lowest unit scoring 38%).

Conclusions: Addressing questions raised by comparative inefficiency could help plans to improve capacity to deal with the growing demand for HD delivered in HDSUs. The application was an important start and needs to be followed by further research to establish model validity and obtain authoritative results.

Keywords: Economics, Efficiency, Data Envelopment Analysis, Haemodialysis, Haemodialysis satellite units

Provision of renal replacement therapy (RRT; i.e., dialysis and transplantation) for patients with end-stage renal failure has been steadily rising in England and Wales. Latest figures show an additional 129 patients per million of population being treated between 1993 and 1998, and this rise is expected to continue into the foreseeable future (1;2). The expansion has been largely due to liberalization of acceptance of older and co-morbid patients onto RRT. Over the course of the previous decade, a significant change has taken place in the mix of care settings used to treat patients on RRT. Both home haemodialysis (HD) and to a lesser extent peritoneal dialysis have declined, whereas hospital HD has grown (1). There has been a major expansion of haemodialysis satellite units (HDSUs) to cope with the demand for hospital HD. By 1999, HDSUs composed 10% of RRT services (1).

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HDSUs are linked to parent main renal units which have a team of nephrologists providing a full range of nephrology services, including inpatient care. In contrast, HDSUs are largely nurse run, providing maintenance HD, and receive medical input from the parent unit. Potential, but as yet unproven, advantages of satellites include improved patient accessibility to services and more efficient use of resources. However, a recent survey of HDSUs in England and Wales identified a range of inputs (e.g. staff : patient ratios) being used differentially across units, raising questions about the relative efficiency of individual HDSUs (6). Renal service providers, as with managers from other parts of the NHS, need to assess performance, particularly in light of the new National Service Framework for Renal Services and keep an open mind about how best to do this (3, 4, 5). It is difficult to derive useful insights about individual performance without linking inputs (e.g., medical and nursing time, dialysis machines) to the outputs achieved (e.g., number of patients treated) adjusted for patient case-mix, to account for all factors affecting performance and compare relative performance of similar units of production. Suitable performance measures are a general challenge for the NHS but it can be helpful to consider judicious use of existing approaches and data collections to provide important insights. This paper reports on a study of apparent comparative efficiency in the delivery of HDSUs in England and Wales and sets out to demonstrate the potential value of data envelopment analysis (DEA). It is the first to apply DEA to any renal service in the UK and provides an important first step toward understanding the performance of HDSUs.

AN ECONOMIC APPROACH

Data envelopment analysis (DEA) is used to quantify the concept of efficiency and is suited to analysis of health services readily disaggregated into distinctive productive units with similar input and output orientations. It is based on a deterministic, nonparametric frontier approach using linear programming techniques. For details, see references 10–13;15. Efficiency is measured by transforming observed data on multiple inputs and outputs into a single efficiency score for each productive unit performing similar tasks in the sample. Scores are calculated by the ratio of weighted sum of outputs to weighted sum of inputs. Efficiency scores range from "0%" (completely inefficient) to "100%" (completely efficient). A unit's score indicates its current position (distance) relative to a "frontier" of best practice. The frontier is constructed as the technically efficient set of combinations of observed inputs used to produce a unit of output within the sample, thus units lying on the frontier score 100%. An efficient unit maximizes the amount of output for a given set of inputs (or the dual of this problem is to minimize the amount of input used to produce a unit of output).

For example, consider four HDSU units (A, B, C, D). The main inputs influencing the number of chronic HD patients treated weekly are number of trained nurses and dialysis machines. Table 1 highlights the steps in assessing relative performance. Each unit uses different combinations of inputs to treat a level of patients per week; the ratios of output to each input depicts the intensity each unit uses that input; a higher ratio is more efficient. In the example, B makes most efficient use of nurses and D most efficient use of machines. They lie on the frontier of best practice (in a two-input, one-output world, the frontier can be drawn as a line between the graphic coordinates for each unit's output/input ratios, i.e., "ratio of patients treated per trained nurse" and "ratio of patients treated per machine"). The less-efficient units, A and C, are measured as the ratio of the distance from the point of origin to each unit's respective co-ordinates divided by the distance from the point of origin to the intersection with the frontier (i.e., the proportional distance each unit is from the frontier, in this example unit A is 88% efficient and C is 93% efficient).

DEA has several strengths and challenges. Strengths include being underpinned by economic theory and methods, focus on relative not absolute efficiency, the facility to

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Table 1. Example of relative efficiency using an illustrative characterisation of HDSUs

Unit	A	B	C	D
Output: Patients treated per week	30	90	60	90
Input 1: WTE trained nurses	2	4	5	7
Input 2: Dialysis machines	12	35	20	28
Output/Input 1: Patients treated per nurse	15	22.5	12	12.8
Output/Input 2: Patients treated per machine	2.5	2.5	3	3.2
Efficiency of trained nurses relative to most efficient unit (%)	66%	100%	53%	56%
Efficiency of dialysis machines relative to most efficient unit (%)	78%	78%	93%	100%
Relative efficiency score, weighted sum of output to inputs (%)	88%	100%	93%	100%

HDSU, haemodialysis satellite unit; WTE, whole time equivalent number.

incorporate multiple inputs and outputs simultaneously, and identifying actual good practice and performance targets. However, in practice it can be challenging to characterize the production process validly. When complex production processes are involved, specifying a model populated with good quality data can be hard for several reasons. In particular, an unmanageable number of variables may be needed to capture the process adequately; the quality of data available may be too poor to provide accurate measurement and produce valid results; or the cost of a specialist data collection may be prohibitive or untimely. As a data-driven deterministic technique, DEA results are highly sensitive to outlier observations, insensitive to statistical noise and the measurement of comparative efficiency rests on the premise that efficient units are genuinely efficient. Main uses of DEA applications in health care management have been to raise important, focused, questions on individual performance (7;9;14;15).

METHODS

Sample and Data Collection Method

A secondary analysis of a survey designed and collected for the main study's first phase, to describe the structure and processes of HDSUs in England and Wales was used (6). Eighty-two HDSUs were in place by the time of the survey (31 March 1999), and 90% completed the survey. These data were the most detailed, current, and complete on HDSUs workload, organization, and processes available.

Characterization of HDSU Production

There is no single correct way to characterize any production process, the aim is to approximate reality as closely as possible with the best data available. In practice, selection of a particular characterization usually depends on balancing clinical meaning, data availability and degrees of freedom allowed to estimate the model. With clinical experts' help, we extracted variables from the survey to characterize a suitable HDSU production process.

A desirable output measure would be one that captured the notion of "maintaining the level of renal functioning in order for the HD patient to survive and enable them to carry out usual activities of daily living with acceptable quality of life." This outcome would require patient-level data on relevant clinical indicators and long-term outcomes (e.g., survival and quality of life) and was beyond the scope of the survey. An alternative approximation for output was "total weekly HD treatments produced per HDSU." This definition, although crude, reflected the primary purpose of HDSUs, numbers of patients receiving twice or thrice weekly maintenance HD. Unfortunately, the measure was unable to adjust for case mix difference for several reasons. Patient-level information on age and co-morbidities were beyond the scope of the survey; no agreement on how to measure patient nursing dependency meant it could not be classified in advance of data collection and infection status was asked for (proportion of patients with HIV, Hepatitis B or Hepatitis C) but incomplete.

Inputs related to the essential health service resources needed to provide maintenance HD; nursing staff, support staff, and available dialysis slots. Nursing and health care assistants (HCAs) are required for attaching patients to machines, monitoring dialysis, and maintaining and cleaning machines. HCAs were a combination of health care assistants, renal orderlies, and renal technicians. Their roles jointly complemented the nursing function as the main source of support staff. Survey data were recorded sufficiently accurately to examine total whole time equivalent (WTE) numbers for all nurses and HCAs but not separated by staff grade. Available dialysis slots reflected capacity for dialysis at the required level of frequency (under stable conditions, this is a function of the number of days a week a unit opens and sessions offered). It was measured by calculating maximum number of dialysis slots available per week (number of dialysis stations times number of sessions) to capture differential use of opening times. It assumes all dialysis machines are available for use and none are under repair, kept as spare, or dedicated for high-risk patients.

The number of inputs was selected on the basis of quality of data available for potential variables (e.g., qualitative aspects of care such as use of dose monitored dialysis, type of filtration, or regularity of water testing could not be incorporated) and, wherever possible, using one variable to represent an associated group of variables (e.g., available dialysis slots was strongly correlated with dialysis stations and machines; therefore, the latter were excluded).

It could be argued that medical nephrology staff cover should be included as an input, particularly where medical care is provided as on-site cover. The survey identified few units with some form of permanent cover on site but, unfortunately, did not collect detailed data on grade and frequency, making it impossible to construct a suitable indicator for the analysis.

Model Structure

The optimization objective was to maximize total weekly number of HD treatments within existing resources available at HDSUs. The base case model assumed a "variable returns to scale" (VRS) relationship between the inputs and output, that is, that units may operate at under, over, or full capacity. This approach seemed realistic as it allowed for the possibility of economies of scale.

Sensitivity Analysis

Sensitivity analysis assessed the impact of uncertainty in three of the assumptions. Assessment of sensitivity was judged by comparing the efficiency scores obtained under each new model variant with scores from the original model (12). The first assumption tested was number of staff currently employed. It was substituted by number of funded posts. In some specialties, including RRT, nursing staff vacancy rates can be high. It was important to estimate the uncertainty associated with these two data sources to understand the extent WTE numbers may underestimate resource inputs. The second assumption tested was the assumption of VRS. This was substituted by constant returns to scale (i.e., where outputs levels change in direct proportion to changes in input levels). This strategy helped to ascertain the extent to which VRS assumptions discriminated between units. Lastly, minimum weights of 20% were placed on two of the inputs variables: nurse (WTE or establishment) and maximum slots (these were based on common practice). These weights guaranteed HDSUs delivered care with at least a minimum level of nursing and equipment (approximated by slots) and were used to check whether outlier values impacted results unduly.

Analysis

The DEA software Frontier Analyst produced the efficiency scores, score rankings, and identified best-practice peers (8).

RESULTS

Response and Activity

Seventy questionnaires from the seventy-four returned were complete enough for DEA modeling purposes. The sample represented 85% (70 of 82) of HDSUs. Two excluded HDSUs were not operational at the time of study and two returned data that were difficult to interpret. The mean observed output level was 108 HD patients per week. The average inputs used was 6.75 WTE nurses, 2.54 WTE HCAs, and 124 available dialysis slots. The difference in maximum slots available and total treatments showed that, on average, 16 slots a week were spare.

Efficiency Scores

The efficiency scores obtained for the sample are described in Table 2. The data show a mean overall efficiency score of 90.4% (median = 97.4%). Thus, on average, if production practices in all HDSUs had followed the practice of the twenty-four best practice HDSUs identified, all else being equal, current levels of mean inputs could have provided 10% more HD treatments. Instead, forty-six HDSUs were identified as potentially underperforming to some extent when compared with best practice peers, 12 HDSUs scored less than 80% efficiency. The least efficient HDSU had a score of 38%. Sensitivity analyses did not significantly change efficiency scores.

Efficiency Improvements

DEA allows systematic and transparent investigation of efficiency improvements for individual HDSUs and setting of targets in relation to best practice peers. For example, some HDSUs appeared to have unused dialysis slots. It would be important to ascertain why these were currently unused to understand if true excess capacity existed and whether it was fruitful to discuss options for reducing spare capacity (e.g., legitimate reasons could include, to cover the risk of machine breakdown or staff shortages and illegitimate reasons poor working practices). Yet other HDSUs in the sample appeared to be underperforming with respect to staffing. All else being equal, one low-performing HDSU (44% efficient) used 0.5 WTE more nursing staff and 0.9 WTE more HCAs but produced eighty-one fewer treatments per week than a peer. Important contextual information needs to accompany

Table 2. Efficiency scores produced for HDSUs in England and Wales using a three input and single output characterisation[a]

	Mean (SD)	Median (IQR)	Minima	Ranking	
All HDSUs ($n = 70$)	90.4% (14.0)	97.4% (86.2–100)	37.5%	100%	24 (34%)
				90–99%	21 (30%)
				80–89%	13 (19%)
				60–79%	9 (13%)
				40–59%	2 (3%)
				<40%	1 (1%)

[a]Three inputs variables were WTE nurses, WTE HCAs, and dialysis slots; output variable was weekly HD treatments. SD, standard deviation; IQR, interquartile range; HDSU, haemodialysis satellite unit.

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any discussion about the value of raising output to match its' peer. For example, it would be important to ascertain whether apparent inefficiency was the result of more time spent talking to patients and relatives/carers and dealing more systematically with other aspects of care.

DISCUSSION AND POLICY IMPLICATIONS

There is a growing need for more HDSUs and stations within existing HDSUs to care for chronic HD patients throughout England and Wales. It seems reasonable to expect that diminishing current inefficiencies within existing HDSUs ought to release resources to facilitate some of the targeted expansion planned for. But to expand wisely, it is important to identify relative performance of individual HDSUs, understand factors that influence performance, determine optimal provision, and plan a coherent strategy for service improvements and expansion. Although this is a substantial agenda, an encouraging start can be made with DEA.

The study has demonstrated that DEA is a judicious approach to use for performance assessment of HDSUs. Not only does the technique incorporate essential interactions between inputs and outputs of the production process but the use of an efficiency frontier of best practice peers allows managers to identify apparently poorer performing units, question why differences might exist, if appropriate quantify target improvements, and assess the extent to which theoretically possible improvements are realistically plausible or desirable. The study has highlighted the importance of data and its quality for DEA. In this instance, a related but not specifically designed survey of HDSUs structures and process allowed for a first estimate of efficiency. By understanding the limitations of the initial exercise, it now becomes possible to design a survey that can compensate for current inadequacies and construct a second generation model to validate the model structure and results.

The characterization of HDSUs modeled was limited to three input variables and a single output. It is likely that this is too simplistic, particularly as HD patients are unlikely to be a homogenous group and there is inter-unit variation in patient factors affecting the process (e.g., age, co-morbidity). Future research is needed to investigate a more suitable characterization and must be done alongside appropriate data collection. Apart from lack of data on medical cover, another example of a potentially omitted part of the production process in this study was transportation of patients to and from HDSUs. Anecdotal evidence suggests transportation arrangements can delay start and finish times of sessions and impact on patient throughput. The input variables used were by necessity highly aggregated. The data that were available did not permit examination of different skill mix and potential for staff substitutions across HDSUs. In particular, there may be important differences in the mix of nursing and HCAs used that was masked and different types of medical input unaccounted for. The output measure was also less than ideal as it omitted to measure differences in the quality of medical care and assumed all units practiced adequate dialysis regardless of their patient case mix or dialysis techniques. It is unlikely that routine measurement of quality of life and patient well-being will become more accepted practice but it is hoped that routine reporting will allow for better output measures to become available in future (16). For example, the UK Renal Registry (16) is collecting data on adequacy of dialysis on an individual patient and unit level basis, therefore, in time, could be used to adjust for quality.

The results presented should be regarded as an opportunity to learn about the potential of DEA rather than as definitive results in their own right. As such, considerable variation was shown to exist in the patterns of resources used by individual HDSUs to deliver care to HD patients. Although this should not be particularly surprising because no guidance has been issued for setting up a "gold standard" HDSU, it is nonetheless important to examine and question such variation with respect to how efficiently resources can be used.

What was not possible to show from these data was whether efficient units were operating at too high a stress level for staff to cope with (i.e., staff "burn out"), leaving them no time for attention to more caring aspects or perhaps appropriate clinical assessment. In which case it would be inappropriate for the less efficient units to emulate so called "good practice." More research is needed to relate apparent technical efficiency to quality of care in the production of renal satellite services.

In summary, this study has demonstrated the use of DEA in raising questions about the comparative efficiency of providers of a discrete clinical service. Addressing these issues might improve the throughput of chronic HD patients and, thereby, capacity to deal with the growing demand for HD delivered in HDSUs. This premise needs to be established by further research. Clearly further studies are required to ascertain whether altering the characterization of HDSUs and improved data is associated with changes in the pattern of efficiency scores and, thus, confirm the value of this technique as a measure of efficiency for HDSUs.

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