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A comparison of actual registered costs and costs derived from diagnosis-related groups (DRGs) for patients undergoing heart transplantation, lung transplantation, and thoracotomy for other lung diseases

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Abstract The Norwegian health care system, like other health care systems in the world, is in the midst of a changing financial environment for hospital reimbursement for patient care. Since 1997 the Norwegian government has introduced a new financing model of block grant and activity-based financing. In this model, diagnosis-related groups (DRGs) play an important role in hospital financing. The initial motive for developing the DRGs was to improve hospital productivity and efficiency and to develop a tool to control increasing hospital costs better. We raised the question as to whether the DRG system in fact covers actual costs in patient groups undergoing heart transplantation ($n = 12$), lung transplantation ($n = 4$), and thoracotomy for other diseases ($n = 10$). A new prospective cost model was developed to measure actual costs related to individual patients. The patients were closely observed and the related data collected during the hospital stay. Each patient's hospital stay was divided into four different categories of resource requirements, defined as heavy intensive care, light intensive care, intermediate care, and ordinary care. In addition, the number of staff involved and the duration of surgery and procedures were recorded, as were medicine costs and material costs. Based on these data, the actual costs for each patient were calculated. These were then compared with the respective DRG reimbursement (100% coverage) for the corresponding group. We found that the median cost for heart transplantation was US$ 50,590 (1 US$ = 7.5 NOK based on the exchange rate at the time of the study), while the respective DRG reimbursement was US$ 65,662. For lung transplantation, the respective figures were US$ 46,668 vs US$ 65,662, and for thoracotomy, US$ 24,307 vs US$ 11,004. We found that our method was applicable to a hospital setting. DRG coverage for heart and lung transplantation seems to overestimate the actual costs. For the thoracotomy procedure, the DRG coverage did not cover the actual costs.

Keywords Cost · Cost analysis · Hospitalization cost · DRG reimbursement

Abbreviations *DRG* Diagnosis-related group · *HCFA* Health Care Financing Administration · *HIC* Heavy intensive care · *LIC* Light intensive care · *IC* Intermediate care · *OC* Ordinary care

Introduction

Diagnosis-related groups (DRGs) constitute a patient classification system that provides a method to relate the type of patients treated in a hospital to the costs incurred by the hospital. The design and development of the DRG system began in the late 1960s at Yale University [7]. The initial motivation for developing the DRG system was to create a framework for the monitoring of hospital activity and efficacy and thus to control increasing hospital costs better.

The DRGs, as they are now defined, form a manageable, clinically coherent set of patient classes that relate a hospital's case mix to the resource demand and associated costs experienced by the hospitals. Through DRGs, hospitals can gain an understanding of the patient population treated, the costs incurred and, within reasonable limits, the service expected to be required [6]. The classification of patients into DRGs is a constantly evolving process. As coding systems change, as more comprehensive data are collected, or as medical technology or practice changes, the DRG definitions must be reviewed and revised.

The main component of the DRG system is a classification scheme consisting of classes of patients who are similar in terms of their consumption of hospital resources. Resource consumption of patients in each DRG must be similar to establish a relationship between the case mix of a hospital and the resources it consumes. The definition of a DRG cannot be specific to the degree that every patient is identical, but the level of variation is known and predictable, and the average pattern of resource intensity of a group of patients in a DRG can be predicted accurately. DRGs are defined based on principal diagnosis, secondary diagnosis, surgical procedures, age, sex, and discharge status of the patients treated.

Total hospital expenditures can be divided into directly patient-related costs and basic costs. Extensive work has been carried out to allocate basic hospital costs (technical units, radiology, intensive care, administration, textile unit, kitchen, etc.) to the respective patient groups [5]. Actual patient-related expenses are divided into different resource categories, such as nursing and surgery. These cost components include various resource factors, such as manpower and medication. The expenses are distributed from the cost groups to the patient groups according to different distribution formulas, resulting in one cost per patient in each patient group (DRG cost).

By comparing the various DRGs, a relative cost can be calculated, namely, the cost weight. The cost weight of 1 expresses the average patient nationwide, and for all patients the relative use of resources is compared with this average patient cost. Thus, each patient is placed in a DRG group, and the system estimates the mean cost of treatment for each group of patients relative to the average patient. In the national DRG system in Norway, the cost weight of 1 for 1997 corresponded to US$ 3334.

In this study, we calculated actual hospital costs for three selected patient groups based on a cost analysis method developed by our group. The aim of the investigation was to compare the actual costs of heart transplantation, lung transplantation, and thoracotomy for other lung diseases with the revenue from the DRG system for the respective groups using our new prospective method.

Table 1 Patient characteristics

	Heart TX	Lung TX	Thoracotomy
Age	53 (21–64)	55 (48–58)	52 (26–70)
Sex			
Male	10	2	6
Female	2	2	4

Patients and methods

We studied patients admitted to our hospital over a 6-month period (January to July 1997) in the following groups: heart transplantation ($n = 12$), lung transplantation ($n = 4$), and thoracotomy ($n = 10$). Patient characteristics are given in Table 1. The time of hospital stay was defined as the duration from hospital admission to discharge from the hospital. For all patients, main diagnosis, secondary diagnosis, operating room codes, and procedural codes were registered. Most of the patients moved between surgical and medical departments during their stay, and data were obtained from all departments. Data were collected daily from the nurses responsible for the patient, from patient records, and from medication lists. In addition, the authors made observations during surgery and other procedures. We used a new prospective method to calculate actual costs related to individual patients.

Time resource categories

Based on close prospective observation, each patient stay was divided into four different resource categories, defined as heavy intensive care (HIC), light intensive care (LIC), intermediate care (IC), and ordinary care (OC). In addition, operating and procedural times and number of staff involved during surgery and major procedures were recorded. We then calculated the actual costs for each patient and the three selected patient groups. The four resource categories were defined based on the need for nursing staff. The investigators determined which of the four major stages of nursing care the patient was receiving at each working shift. This was determined by daily observation and direct information from the responsible nurse as well as from registration forms, which included the number of directly dedicated nurses involved in the care of the patient in each working shift.

Disposable products and medication costs

Costs for disposable materials and drugs, including blood products and volume expanders, used in the operating room or thereafter during procedures and at each level of nursing care were registered. Costs exceeding US$ 14 daily were ascribed to the individual patient's record.

Operating time and resources

The time from arrival in the OR to discharge from the OR was recorded as well as the number of personnel directly involved in the care of the patient during the operating procedure (surgeons, nurses, anesthesiologists, perfusionists). The time multiplied by the number of dedicated personnel was calculated for each patient stay in the OR.

Procedural time and resources

All procedures, such as lung biopsy, pleural drainage, tracheotomy, consultations from other specialists, CT scans, ultrasound, etc., were observed. When the number of personnel multiplied by the time involved exceeded 1, the procedure was recorded for the actual patient. If less than 1 (personnel × hours), the cost was not distributed to the single patient, but seen as part of the total hospital cost; examples for this are blood sampling, physiotherapy, and ordinary X-rays.

Methodology of cost assessment

Our study was restricted to hospitalization costs, and cost information was collected by means of the method of prospective registration. The following cost items were measured for each patient included in the study:

Total costs per unit

The operating cost per unit is based on the individual unit's operating cost and its share of the hospital's overall operating costs. Doctors' salaries were deducted from the total and re-apportioned to the respective operating surgery unit's costs according to time spent in operating units.

General hospital expenses were divided among the clinical departments and surgical sections involved to determine the units' shares of common costs. These were defined as final cost centers. Operating expenses for common functions were transferred to the final cost center according to different key figures. Costs for the following areas were transferred in relation to the number of patient discharges: administration, central nursing section, economy section, patient library, central office staff, and hospital clergy. Costs for cleaning and property management were divided according to floorspace. Central IT expenses were transferred in relation to the number of PCs installed in each unit. The costs for personnel department, corporate health service, in-house training section, section for epidemiology, and medical library were diverted to the primary cost centers based upon the number of employees. The following expenses were transferred according to the number of total hospital stays: clinical chemistry, radiology, physiotherapy, kitchen, textiles, sterilization unit, social medical unit, medical technical unit, pathology department, management department, and department for hygiene. The costs for intensive care were transferred based on the activity register for the actual unit.

Total costs per clinical department (the unit's operating costs for the financial year plus the shared costs) were divided by the total number of days of stay in the unit for the same time period. This gives the mean cost per stay per day for the unit. We then correlated the mean cost per day with the use of nursing personnel resources attached to the unit. Based on the correlation of number of beds and nurses for the studied departments, they were classified as belonging to one of the following categories: HIC (> 1 nurse per patient), LIC (0.5–1 nurse per patient), IC (0.25–0.5 nurses per patient), or OC (< 0.25 nurses per patient). Thus, each department was assigned to a personnel resource category. We assumed the cost relation between HIC, LIC, IM, and OC as 4:3:2:1, respectively. When calculating the costs per day for a patient requiring ordinary care in an OC unit, the unit's mean daily costs were multiplied by 1. However, if the patient was in need for intermediate care for a period of time, the mean costs were multiplied by 2 for that period.

Costs attached to operating time

Costs for surgical operating units were based on the last fiscal year. To this number was added the estimated share of the surgeons' and anesthesiologists' salaries as well as an estimated share of the cost for anesthesia (nurses and equipment). Doctors' salaries are included in the various departments' budgets, from which a part, proportional to the time worked in the individual operating units, was re-allocated to the respective OR. Costs for anesthesia services were based on total costs for the Department of Anesthesia which were transferred to the different operating rooms according to their relative use of anesthesia hours per year. The operating rooms' share of some of the common hospital costs like social expenses, textiles, cleaning, heating, and property management was not included.

To estimate the cost of personnel per hour, we divided the total cost per surgical unit by the total amount of personnel-hours. This was calculated by taking the estimated mean number of personnel dedicated to surgical procedures (surgeons, anesthesiologists, OR nurses, anesthesia nurses, perfusionists) for each of the studied ORs multiplied by the total OR working hours as registered in the anesthesia records. This result indicated total operating room personnel-hours for the unit. The total cost for each OR unit divided by the amount of personnel-hours for the unit gave the mean cost per personnel-hour for the unit.

Costs attached to procedures performed outside of the OR

Costs for more extensive procedures performed in the units were calculated for each individual patient. When the time (in hours) multiplied by the number of personnel involved exceeded 1, the procedure was recorded. Costs attached to procedures were estimated by using the same cost per personnel-hour as calculated for the corresponding operating room.

Results

The mean length of stay for heart transplantation was 33 days (range 10–65 days); for lung transplantation, 29 days (range 16–43 days); and for thoracotomy,

Table 2 Patient characteristics and resource utilization / cost items (*HIC* heavy intensive care, *LIC* light intensive care, *IC* intermediate care, *OC* ordinary care)

	Heart TX	Lung TX	Thoracotomy
DRG code	103	495	75
DRG cost weight	19.69	19.69	3.3
DRG cost in US$ for 1997	65,662	65,662	11,004
Mean length of stay in days (range)	33 (10–65)	29 (16–43)	30 (8–52)
Mean hospital stay in different resource groups in hours (range)			
HIC	151 (14–366)	161 (27–377)	21 (5–40)
LIC	91 (87–196)	68 (40–123)	49 (7–57)
IC	52 (7–193)	118 (82–268)	13 (23–52)
OC	491 (222–1295)	326 (624–678)	524 (97–1198)
Median hospitalization costs in US$ (range)	50,590 (33,435–134,512)	46,668 (38,892–84,548)	24,307 (9398–65,440)
Median operating room costs[a] in US$ (range)	9720 (4723–63,058)	6282 (2905–12,317)	2559 (1929–3413)
Median personnel costs in US$ (range)	31,704 (9940–123,991)	39,114 (8804–28,557)	19,433 (9750–40,199)
Median pharmacy/laboratory costs in US$ (range)	3109 (2318–43,853)	6273 (1221–11,835)	256 (125–275)

[a]Operating room costs include OR-personnel costs as well as OR-related material, pharmacy, and lab costs

Table 3 Mean hospital stay cost per day / nursing resource categories for three departments (*LIC* light intensive care, *IC* intermediate care)

	Dept. of Cardiothoracic Surgery	Medical Dept.	Dept. of Respiratory Diseases
Number of hospital stay days	12,041	16,382	4696
Mean hospital stay cost per day (in US$)	1110	943	974
Number of nurses	83.75	61.5	19
Number of beds	46	50	18
Number of nurses per bed per day	1.82	1.23	1.05
Number of nurses per bed per shift (3 shifts per day)	0.61	0.41	0.35
Nursing resource category	LIC	IC	IC

30 days (range 8–52 days). The total length of stay in hours for the patients undergoing heart transplantation ($n = 12$), lung transplantation ($n = 4$), and thoracotomy ($n = 10$) are listed in Table 2.

Total costs per unit

We used the above method to calculate the costs for the three departments involved in the study: Department of Cardiothoracic Surgery, Medical Department, and Department of Respiratory Diseases. The costs were apportioned to each department in proportion to the consumption of total common resources – the shared cost. Such shared costs include electricity, laundry, meals, etc. Thus, for each department the daily cost per stay is given by: total costs = shared costs + operating costs.

We divided the three involved units into different resource categories by dividing the actual number of employed active-care nurses by the total number of beds for the respective unit (adjusted for actual occupancy percentage) (Table 3). Based upon the personnel resource profile, the costs per day for the units were calculated according to the level of care (Table 4).

Costs attached to operating time and procedural time outside of the OR

The total operating costs of the OR include (among other things) surgeons' salaries (estimated at 60% of total surgeons' salaries), and anesthesiologists' salaries (85%). The Department of Anesthesia's costs for each OR were estimated at 22% (on average) of the total, based on activity records.

We estimated the mean number of personnel dedicated to the surgical procedures to be 8 (3 surgeons, 2 OR-nurses, 1 anesthesia nurse, 1 anesthesiologist, and 1 perfusionist). Total OR working hours per year as registered in the anaesthesia records were 6625. Thus, total personnel-hours are 53,000 (8×6625). This gives an estimated cost per personnel-hour of US$ 149 (Table 5).

Actual cost and DRG-derived costs for heart transplantation

The actual cost for each patient and the difference in actual cost and DRG-derived cost are shown in Fig. 1. The

Table 4 Cost per day according to level of care. We calculated the cost for ordinary care (cost per day / nursing categories × 0.25) and estimated the cost relation between ordinary care (*OC*), intermediate care (*IC*), light intensive care (*LIC*), and heavy intensive care (*HIC*) as 1:2:3:4, respectively

	Dept. of Cardiothoracic Surgery	Medical Dept.	Dept. of Respiratory Diseases
Cost per day (in US$)	1110	943	974
Nursing category	OC 0.61	IC 0.41	*IC 0.35*
Calculated cost for each level of nursing (in US$)			
OC	451	675	608
IC	910	1348	1217
LIC	1365	2022	1826
HIC	1821	2697	2435

Table 5 Total cost for the Department of Cardiothoracic Surgery's OR and cost per personnel per hour (see text)

Budget (in 1000 NOK)	38,486
Surgeons' salaries (in 1000 NOK)	10,219
Anesthesiologists' salaries (in 1000 NOK)	6126
Dept. of Anesthesia (in 1000 NOK)	5153
Total cost (in 1000 NOK)	59,984
Personnel hours in OR	53,000
Cost per hour per personnel (in US$)	149

median cost is US$ 50,590. The corresponding DRG-derived amount for 100 % revenue is US$ 65,662.

Actual cost and DRG-derived costs for lung transplantation

The actual cost for each patient and the difference in actual cost and DRG-derived cost are shown in Fig. 2. The median cost is US$ 46,668. The corresponding DRG-derived amount for 100 % revenue is US$ 65,662.

Actual cost and DRG-derived costs for thoracotomy

Figure 3 shows the actual cost for each patient and the difference in actual cost and DRG-derived cost. The median cost is US$ 24,307. The corresponding 100 % DRG revenue is US$ 11,004.

Data analysis

Substantial variation between hospitalization cost and hospital revenue is likely to occur. We performed a Wilcoxon signed rank test for nonparametric data. Comparison in pairs between heart transplantation, lung transplantation, and thoracotomy groups was performed by univariate analysis of variance. Results show that the hospitalization cost for lung transplantation lies between the two other patient groups, and there was no statistically significant difference. There was a statistically significant difference between the thoracotomy and heart transplantation groups. For these tests, the *P* value was two-tailed and a *P* value of 0.05 was considered statistically significant. The tests were performed by means of SPSS 9.0 for Windows.

Discussion

DRG is a tool to group hospital stays based on medical and administrative data. The cost weights express the estimation of relative cost for hospital stay and are used, among others, for reimbursement in the financing of hospitals. The cost weight states the mean requirement of resources in each DRG group. The basis for calculation of cost weights comes from calculated mean cost estimation per hospital stay for each of the nearly 500 DRGs of the Health Care Financing Administration (HCFA) collected from selected hospitals. Ideally, the DRG coverage for a defined therapy should reflect the hospital costs connected with the performance of the specific treatment. Different versions of the DRG system exist. During our study period, HCFA-DRG Version 8 was used.

The national DRG weights in Norway are based on a top-down method using accounting data from a selection of Norwegian hospitals in 1991 with some later adjustments. In this study we have used a prospective method to measure the actual cost for each patient during the hospital stay. These costs were then compared with the respective DRG reimbursement (100 % coverage) for the same groups. By our method we found that the median cost for heart transplantation was US$ 50,590 while the respective DRG reimbursement was US$ 65,662. For lung transplantation the respective figures were US$ 46,667 vs US$ 65,662, and for thoracotomy for other lung diseases, US$ 24,307 vs US$ 11,004.

The actual DRG coverage for heart and lung transplantation seems to overestimate the actual costs. For thoracotomy procedures for other lung diseases the DRG coverage does not cover the actual costs.

The study has its limitations, the small number of patients in each treatment category prevent us from being

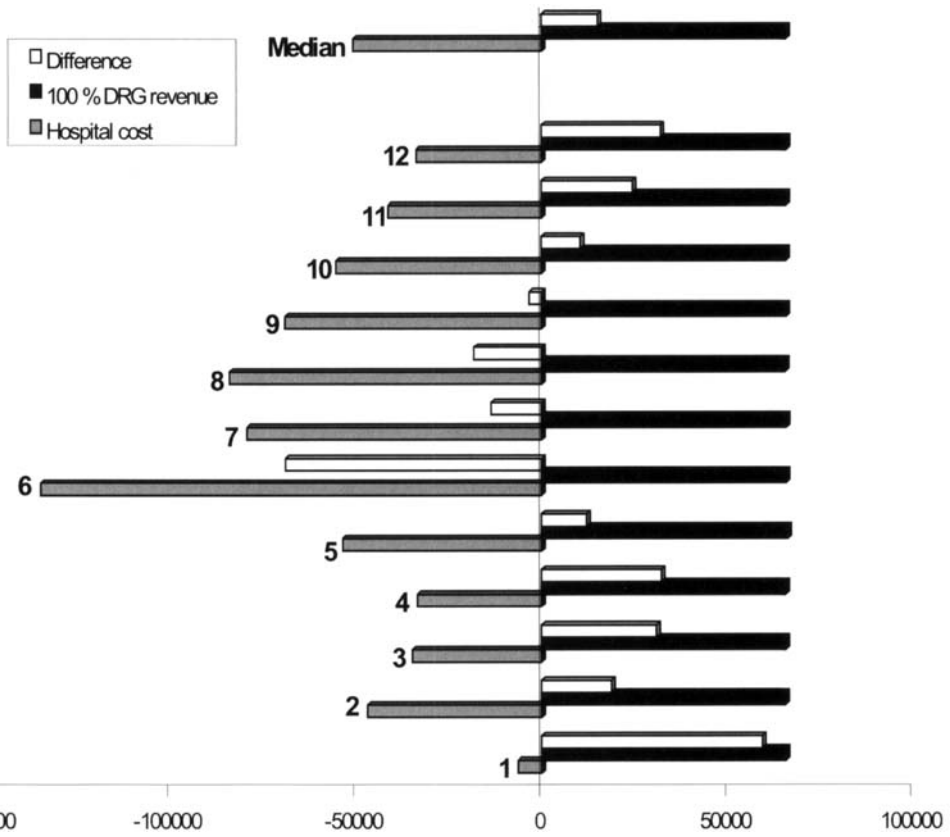

Fig. 1 Actual hospital cost and DRG revenue as well as their difference (actual cost–DRG revenue) for heart transplantation: median values and values for each of the 12 patients are shown. Amounts in US$

sure that the calculated cost is representative. Because of the small sample in each group and the fact that patients are drawn from only one medical center, sampling bias may be an issue. However, prospective consecutive patient selection constitutes an important strength of this analysis, which ascribes costs to individual patients based upon their use of individual resources.

Implementation of such cost data from one center to another must be done with caution. This is necessary to express cost data, which are independent of country inflation, so that the results of cost studies carried out in different countries and at different times can be compared. Expenses and income related to university functions are not incorporated in our model.

The actual costs of transplantation procedures are largely unknown and difficult to obtain. These costs obviously vary from one institution to the next and are often buried beneath hospital billing paperwork. We limit our definition to the operative admission because we compare it with the DRG revenue for that admission. Votapka et al. [11] reported for heart transplantation that total costs for patients associated with United Network for Organ Sharing-status 1 were a mean US$ 239,375 (range US$ 89,910–US$ 512,331) and for status 2 patients were US$ 128,594 (range US$ 63,885–US$ 455,680).

In a retrospective study, Gartner et al. [8] reported for lung transplantation a median cost of US$ 94,324 (range US$ 63,405–US$ 598,482). They based the costs on adjusted charges for surgical admission plus physician fees. Ramsey et al. [10] found that the transplantation charges for lung transplantation averaged US$ 164,989. The cost estimation was based on hospital billing service and was done retrospectively. They also reported that two-thirds of care costs were incurred after transplantation.

Existing accounting system controls are suitable for getting information on the use of resources by each of the cost centers at each moment of time. The system does not manage to link this information with meaningful clinical activities, e.g., heart transplantation. Such activities are a result of a complex interplay between many departments and cost centers. The accounting systems in common use in Norway are not capable of calculating what a specific clinical activity is costing the hospital [2]. For accurate cost estimation, continuous registering of actual medical activities given to the specific patient is required as well as calculation of all overhead costs per patient.

We used a prospective method for calculation of hospital costs for each patient's hospital stay. Calculations of costs are based on the department's internal account

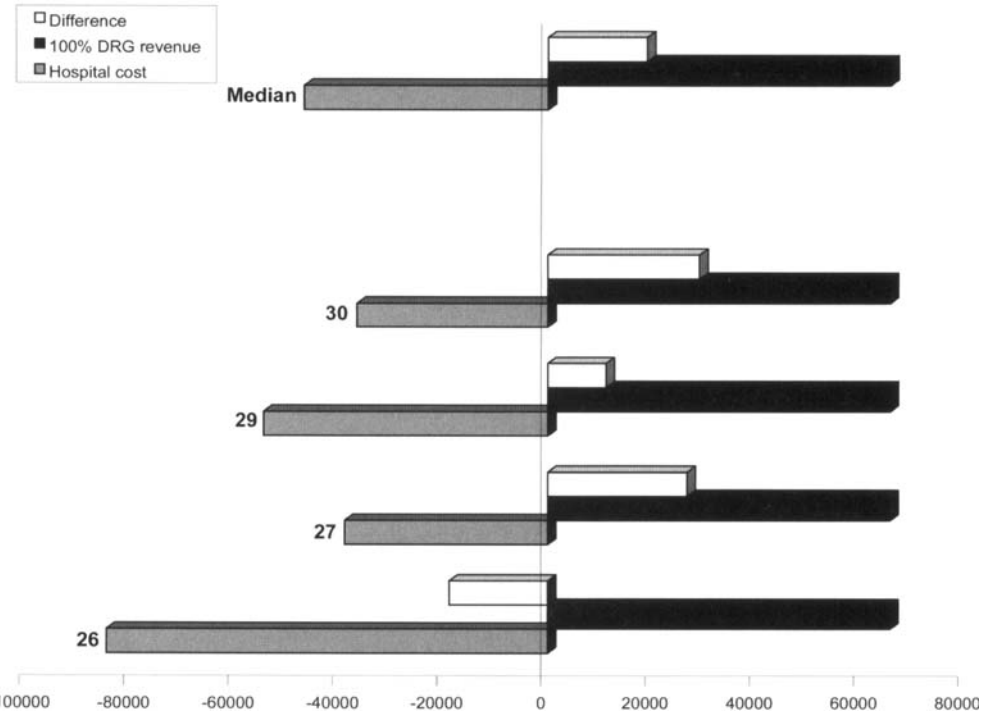

Fig. 2 Actual hospital cost and DRG revenue as well as their difference (actual cost–DRG revenue) for lung transplantation: median values and values for each of the 4 patients are shown. Amounts in US$

added to the shared part of common operational costs and doctors' salaries. Indirect costs were transferred to the department according to defined keys. Salaries of surgeons and anesthesiologists were divided according to time spent in and outside of OR. Calculation of costs using a prospective method is superior to a retrospective view, as cost from intensity of nursing varies over time and can only be measured by observations during the stay.

We have divided costs attributed to days spent in the hospital into four subgroups depending on the need for nursing personnel [4]. Costs attached to operating time were distributed according to dedicated personnel-time in the operating room. We have chosen to add laboratory expenses (e.g., blood tests) and minor radiological procedures to common costs, while more expensive articles of consumption (exceeding US$ 14) were transferred to each of the patients.

The official DRG estimation of cost weight in Norway is based on top-down methods. It is therefore of interest to compare our estimations by using a bottom-up method with the DRG revenue for the same patient groups. The bottom-up prospective method we have been using is resource-demanding, as actual costs and activity for each patient are registered throughout the course of the hospital stay. The advantage is that it provides the possibility to analyze variance among patients in each patient group, which cannot be detected by top-down methods. The drawback can be that expenses are overlooked. In top-down methods, total hospital costs form the basis, which are distributed to end products through a set of distribution formulas. This method is less resource-demanding and secures that all expenses are included [5].

The National University Hospital is the only transplant hospital in Norway. In Norway, the DRG cost weights are based on calculations made for the same procedures as in Sweden, and not on any specific Norwegian studies. We found that the median costs in the 1998 study corresponded well with the cost estimates based on Norwegian DRG weights for 1997. This supports the findings that the DRG cost weights used for heart and lung transplantation are well funded. It must be expected that there are some patients who are much more demanding and with higher associated costs than the average patient [1, 8, 9, 12]. The reason for the variation may be differences in patient selection, in the number of patients in the study, and in cost-effectiveness between institutions as well as method discrepancies [12]. The medical treatment also changes, and the basic cost weight estimations may change if treatment varies over time or if other patient groups are being treated [3]. With improved techniques, experience, and increased volume, cost should decline.

For thoracotomy procedures for other diseases, we found that the actual costs were higher than the cost derived from the DRG system in 1997. The DRG weight for these hospital stays is based on calculations from selected Norwegian university and community hospitals. The reason for the difference is most likely attributable

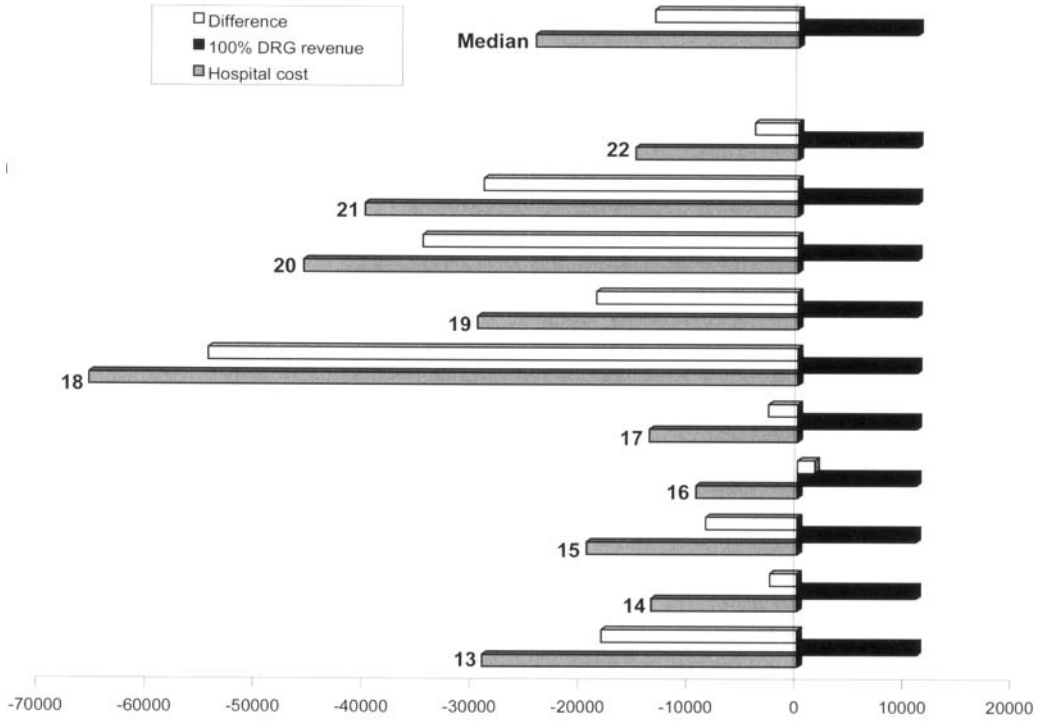

Fig. 3 Actual hospital cost and DRG revenue as well as their difference (actual cost–DRG revenue) for thoracotomy for other diseases: median values and values for each of the 10 patients are shown. Amounts in US$

to differences in patient selections, but may also be caused by cost-ineffectiveness at our institution or method discrepancies [12]. The medical treatment also changes, and the basic cost weight estimations may change if treatment varies over time or if other patient groups are being treated. Compared with the heart transplantation group, the patients undergoing thoracotomy procedures for other diseases had statistically higher variation costs (Mann-Whitney test). The small number of patients studied and the more heterogeneous disease processes may also explain the variance observed in the thoracotomy group.

An increased use of bottom-up actual cost methodology combined with the direct allocation of overhead costs is recommended to calculate real costs for patient treatments [2, 9]. This allows the study of interpatient variations in the consumption of resources. Our method fulfills these criteria. We found that the method was relatively uncomplicated to implement. However, a prospective bottom-up method will necessarily be resource-demanding. By further development it may be possible to simplify parts of the method without impairing the result. For instance, we found that costs for medicine and disposable products for most of the patients were very low compared with the other estimated costs, and thus these costs may not need to be registered specifically for the actual patient on a daily basis as done in our study.

The current health care environment mandates closer scrutiny of health care cost allocation as well as medical outcome. The governmental funding of hospitals in Norway is now partly bound to reimbursement based on the DRG system. This way DRG is supposed to be an incitement for the hospital to increase productivity and health care service. To accomplish this, it is important that the actual reimbursement based on the DRG code is able to predict the actual costs. We found that for our institution a 100% DRG reimbursement did not correspond to actual costs for all groups studied. However, for most of the groups there were reasonable correlations. The result of our comparatively small, single-institution sample must be regarded as preliminary, although the method used can be compared to larger studies. Our simplified prospective method seems to be an acceptable tool for measuring patient-related costs. Repeated follow-up observations will be of value to evaluate the costs over time.

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