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Estimated costs of postoperative wound infections

A case-control study of marginal hospital and social security costs

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SUMMARY

A cohort of 4515 surgical patients in ten selected intervention groups was followed. Three hundred and seventeen developed postoperative wound infections, and 291 of these cases were matched 1:1 to controls by operation, sex and age. In comparison to the controls the cases stayed longer in hospital after the intervention and had more contact after discharge with the social security system.

Using data from a national sentinel reference database of the incidence of postoperative wound infections, and using national activity data, we established an empirical cost model based on the estimated marginal costs of hospital resources and social sick pay. It showed that the hospital resources spent on the ten groups, which represent half of the postoperative wound infections in Denmark, amounted to approximately 0·5% of the annual national hospital budget. This stratified model creates a better basis for selecting groups of operations which need priority in terms of preventive measures.

INTRODUCTION

While an increase in the prophylactic administration of antibiotics [1] has reduced the incidence of postoperative wound infection (PWI) thousands of patients still acquire these infections every year after surgical treatment in Danish hospitals [2]. The Danish hospital system is almost totally financed by taxes and in Denmark expenditure on hospitals amounts to 6·0% of the Gross National Product (GNP) compared to 11·2% in the United States [3].

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In order to estimate the magnitude of the problem in Denmark, the State Seruminstitute established a sentinel database for PWI in 1991. Since then departments of general surgery, orthopaedic surgery and gynaecology have been participating. Twice a year the database is updated, and a summary of the results is mailed to all 163 surgical departments in the country [4]. A comparison has been made with the National Health Register's latest complete data covering the year 1991. We found that 12% of the total surgical activity was represented in the sentinel system for that year.

There is only limited information on the human consequences of PWI. It is known that infected patients have a prolonged stay in the hospital [5] compared to uninfected patients and on average infected patients in the Danish sentinel system stay 14 days extra in hospital, which corresponds to 45000 extra bed days per 100000 operations. Though PWI is a potentially serious complication in surgery, it is at least in part preventable [6–13] and a reduction in its incidence will therefore increase efficiency in the hospitals.

Hospital costs are divided into overheads and variable costs [14]. The former are independent of the size of production. They include expenditure for buildings, heat, light and basic staff. Variable costs covers treatment, medicine, food and the staff needed for more than basic activities.

Hospital costs are most often published as average figures such as mean costs per bed-day [15]. A more accurate method is to include marginal measurements [16]. This method focuses on the economic consequences of hospitalizing or discharging one more patient compared to maintaining the status quo. It should therefore follow that the marginal costs converge to the average costs when the number of occupied beds increases to the maximum capacity. The reason is that the overheads for the last patients are low. On the other hand if the hospital has to open an extra operating theatre with new staff to treat the next patient, this one patient will be extremely expensive to treat.

We found only a few studies that included derived costs in the primary health care system and the social security system [17–20]. They are generally selective in their choice of interventions, which limits the possibility of utilizing the expertise to other surgical areas.

In this study we have collected register based data on a historical cohort of patients with PWI and matched them with noninfected controls to determine whether registers were an easily accessible way to obtain information on main costs. We describe the use of an empirical cost-model which includes data on marginal costs in order to estimate some of the important health economic consequences of PWI. The data for the study was collected from the infection records of one hospital over a period of 4 years and from the municipal social records.

MATERIALS AND METHODS

The hospital of the municipality of Frederiksberg serves a population of 80000 people. Infections are registered according to the Danish guidelines [21], and include all those in hospitalized patients who have undergone a surgical procedure in which an incision is made through the skin and is followed by primary suture. Endoscopic procedures not involving incisons and anal surgery were not included

Table 1. *The final population of* 1 *to* 1 *matched cases and controls divided in ten surgical groups*

Surgical group	Number of patients
Amputations	72
Fracture of the hip with internal fixation	18
Other fractures with internal fixation	36
Replacement of hip	34
Hernia	42
Stomach and duodenum	56
Gallbladder and pancreas	64
Appendix	84
Colon	30
Urinary surgery	146
Total	582

in the registration [7]. Between 1 January 1985 and 1 December 1988 the departments of orthopaedic and general surgery carried out 8996 surgical procedures, 512 of which resulted in PWIs (5·7%) [5]. Ten surgical groups involving 4515 operations were selected for further analysis, on the basis that they provided a large sample of infected patients and controls (Table 1). These groups included 317 (7·0%) infected patients who were sought matched 1:1 with controls on the operation code and on sex within four different age groups (16–34 years, 35–59 years, 60–67 years and +67 years).

Of the 317 cases 241 were matched on all criteria. Of the remaining 76 cases, 27 were impossible to match directly on the operation code. Instead they were incorporated into related operation groups; 23 cases were matched with a neighbouring age group. Four cases could only be matched on sex, and 22 cases were readmissions. We excluded the last 26 cases so that 291 case-control pairs constituted the final material of the investigation (Table 2).

Discharge dates were missing for ten of the cases. To establish a conservative estimate of the length of hospitalization, the postoperative bed days were defined as the length of the preoperative stay plus one day.

For two controls and two cases we only had the number of postoperative sick-days. The social costs for these four patients were determined from the average per day costs for the rest of the social clients.

Social costs

A person has to be at the disposal of the labour market in order to obtain sick pay. He/she has to be less than 70 years of age and is not allowed to collect a full-time pension. The social register was only able to give information on the two last conditions. Consequently, 113 out of 143 patients between the age of 16 and 70 years was the maximum number that could be entitled to receive sick pay.

A total of 370 patients had had at least one contact with the social office of the municipality of Frederiksberg within the first 12 months after the operation. A social consultant scrutinized all these files. If the patient had received sick pay an assessment was made as to whether PWI was a direct cause or a contributary cause of this payment.

Odds ratio (OR) with 95% confidence limits were calculated.

Table 2. *The composition of the material of the investigation*

Wound infection	Admission to hospital 1 January 1985–31 December 1988			Visiting the social security office during the first 12 months postoperative		Potentially legitimate sick pay receivers	Social files established	Received sick pay
	All	16–70 years	+70 years	16–70 years	+70 years	16–70 years	16–70 years	16–70 years
+	291	117	174	88	132	72	40	24
–	291	127	164	55	93	41	31	12
Total	582	244	338	143	225	113	71	36

Hospital files

All but one of the 36 hospital files on patients with a long-standing sick leave were found. The purpose was to note surgical and medical diagnoses, the amount of medical supervision, and if the patient had had a postoperative stay in the intensive care unit lasting more than 24 h. The number of reoperations, readmissions and breakdowns of wounds were counted.

Wilcoxons rank sum test were utilized as the statistical method.

Cost model

As an approach to estimate the marginal costs for hospital services, we used the results of a Norwegian investigation [22,23] to estimate the costs of different interventions. Diagnosis related groups (DRG) are well known in the US health care system, but the Scandinavian countries do not make explicit budgeting. The reason for using the Norwegian model is that the organization of the healthcare systems in Norway and Denmark as well as the cost levels are almost identical. The Norwegian model was developed as a consequence of the difference [24] between the US and the Scandinavian health care systems and must be regarded as experimental. From other studies involving direct cost estimation in Denmark, the Norwegian cost rates seem to be fairly comparable [25,26]. According to the diagnosis which they are given on admission, patients are categorized as one of 470 different DRGs. The next step is to assign a cost weight to every DRG based on the variable costs and the average bed days.

According to the Norwegian DRG-model only a few selected complications will result in a higher reimbursement. PWI is one such. Apart from the above considerations, there have been no similar attempts to estimate hospital costs in the Danish health care system for the procedures and complications involved in this project.

When estimating the DRG-based marginal costs we use a value of the overheads equivalent to 56 % of the average bed day costs, corresponding to 250 US$ (1990 price-index, 1US$ = 6·50 DKr). As to social expenditure, the sick pay covers the total postoperative period, regardless of who pays the cost burden, the public or the employer.

The latest complete information available on the operative activity was drawn from the National Health Register covering all 12 months in 1991. PWI incidences were extracted from the sentinel system. The ten surgery groups represented respectively 29 % and 37 % of the interventions recorded in these two systems. There was a close correspondence between the relative surgical activity for all surgical groups and age groups in the sentinel system and the National recordings, except for two strata. Appendectomy and herniorrhaphy were over-represented in the sentinel system by respectively 90 % and 40 % for the youngest patients. The date of discharge was registered for only 26 % of the 57775 patients who have been recorded in the sentinel system. Hence the uncertainty of the postoperative length of stay in the hospital was too large in 6 out of 20 strata. The average length of the postoperative stay for all the remaining operations in the sentinel database was used as an approximation (Table 3).

Table 3. *Surgical activity in Danish hospitals for* 1991. *Numbers for incidents of postoperative wound infections, related extra bed days. The DRG based cost weights relates to a Norwegian model. Six of the strata* (*) *had insufficient data to give a reliable estimate of the extra bed days. The average for all other types of operations in the sentinal system has been used instead*

Surgical group	Age (y)	Number of operations	POW incidence	DRG weight	Extra bed days
j	i	A	P (%)		
Amputations	= < 70 y	1040	9·75	2·73	23·22
	> 70 y	1245	8·74	2·73	2·09
Fracture of the hip with internal fixation	= < 70 y	1259	2·94	1·53	14·02
	> 70 y	5245	2·52	1·83	12·97
Other fractures with internal fixation	= < 70 y	4696	2·44	1·27	12·43
	> 70 y	1556	3·63	1·17	20·21
Replacement of hip	= < 70 y	1889	2·38	1·53	2·07
	> 70 y	3359	5·31	1·83	18·18
Hernia	= < 70 y	7240	2·01	0·84	3·07
	> 70 y	3041	2·90	1·07	5·34
Stomach and duodenum	= < 70 y	1905	5·54	2·76	6·96
	> 70 y	1250	8·10	4·61	14·07*
Gallbladder and pancreas	= < 70 y	3122	1·99	2·4	14·07*
	> 70 y	1206	5·69	3·52	14·07*
Appendix	= < 70 y	4992	3·44	0·88	2·88
	> 70 y	406	11·00	1·68	35·87
Colon	= < 70 y	1965	8·24	3·04	14·07*
	> 70 y	1884	7·99	4·05	15·35
Urinary surgery	= < 70 y	2738	2·99	2·31	14·07*
	> 70 y	1435	3·81	2·99	14·07*

RESULTS

Hospital costs

On average cases stayed 5·7 extra postoperative days in hospital compared to the controls (26·6 versus 20·9 days; $p < 0{\cdot}0001$). Twenty-five percent of the patients were below 62·4 years old, and the 50% and 75% percentiles were respectively 72·1 and 79·9 years. Patients who had passed the age of 70 stayed twice as long in the hospital after the operation compared to younger patients. A PWI additionally increased the mean stay for the older patients by 4·2 days (32·0 versus 27·8 days; $p = 0{\cdot}041$). For the younger the difference amounted to 6·9 days (18·7 versus 11·8 days; $p < 0{\cdot}0001$).

The surgical intervention codes did not show that more cases than controls had been operated for malignant diseases.

Social costs

As displayed in Table 2, 368 of the 582 patients had at least one contact with the social security office during the first 12 months after the index operation. Cases had an increased risk of being in this group (OR = 2·99 (2·07–4·33; $p < 0{\cdot}0001$)).

Seventy-two cases and 41 controls were the maximum number that could possibly meet the requirements for receiving sick pay. Social files existed for 40 of the cases and for 31 of the controls. A long lasting sick leave resulted in social security benefit for 24 cases and 12 controls. For the 244 patients under 70 years of age there was an OR of 2·47 (1·11–5·57; $p = 0{\cdot}024$) that a patient would have received sick pay from the social security system if he had had a PWI. The average period of sick leave for the 36 patients was 200 days irrespective of whether they were cases or controls.

During the 4-year investigation period the 36 patients received a total of approximately 350000 US$ as compensation for the loss of earnings. Each case received 50% more per day on average than a control which can only be explained as follows. A person on sick leave could at most obtain a compensation of 90% of his normal wage. Moreover there was an upper limit for compensation. The social security office's explanation of the difference is that the cases had better paid jobs and therefore received maximum compensation more often than the controls, or that more of the controls may have had part time jobs. Eight cases and three controls of the 36 patients ended up with an early retirement pensions.

It was not possible to use the electronic records in the social security system to get information about short time sick leave. Although home-care activities were managed from the social security office, the electronic data processing (EDP) system was not designed for recording the extent of the provision. Neither the medical files nor the nurses hospital files were able to provide us with this information.

Data on the patients usage of nursing home facilities, disability aids, social help towards rebuilding of homes and public delivery of foods could not be strictly compared. One explanation is that the time which elapses between when a person first realizes his need for an aid, when he demands it, and finally when he/she is permitted to have the aid is unknown. This makes a causal relationship with a specific operation or wound infection very uncertain. But overall we found no marked differences between the two groups, and this might indicate that there were no substantial differences in the health status.

Hospital files

For 35 out of the 36 patients (23 cases and 12 controls) with accessible hospital files, and with long standing sick leave, 3 cases and 1 control had diagnoses of malignant disease. Eleven of the 23 cases were readmitted in total 19 times, because of sequelae from PWI.

For the 11 patients who ended up with early retirement pensions, the diagnoses for the 3 controls were: oesophageal varices and cirrhosis of the liver, gangrene of the foot and peripheral arterial insufficiency. The diagnoses for the eight cases were inguinal hernia, gastric ulcer and arteriosclerosis, cholecystolithiasis with pneumonia and hepatomegaly, intraperitoneal abscess, rectal carcinoma with metatstases, peripherial arterial insufficiency, fractured leg and fracture of the foot. The social consultant judged PWI to have a direct causal relationship with the postoperative illness for 5 out of these 8 cases, and a possible relation for a further one.

Cost model

The empirical marginal based cost model for the extra expenditure caused by PWI is shown in Figure 1. For the two age groups 16–70 and 70+ years (i), the

$$\text{Costs} = \sum_{i=1}^{i=2}\sum_{j=1}^{j=10} ((\Delta L_{ij}{*}c_{wij}{*}c_{inf}{*}P) + {*}E_A{*}S{*}(K{*}F + \Delta L_{j}.{*}0,8)/E_P){*}A_{ij}{*}I_{ij}$$

Fig. 1. A model for estimating marginal based hospital and selected social costs to show the resources lossed on postoperative wound infections. If only *direct* marginal costs, as an equivalent of the variable costs are of interest, then the share that originates from the fixed costs (P*ΔL) has to be subtracted.

i, age groups (16–70 y, and +70 y); j, surgery group (1–10); ΔL, average extra bed days for the infected in stratum ij.; c_{wij}, DRG-based cost weight for stratum ij; c_{inf}, DRG-based additional cost weight for postoperative infection; P, Overhead (250 US$ per day); E_A, The latest corrected number for the fraction of the population who had a job (0·793); S, Sick pay (52·5 US$ per day).; K, Additional risk of getting a prolonged sick leave if the patient is a case; F, Postoperative sick leave for the goup with an extended period out of job; A_{ij}, The yearly frequency of surgical interventions in Danish hospitals; I_{ij}, The cumulative incidence of surgival wound infections in stratum ij.

PWI-related extra hospital costs and sick pay are calculated for each of the ten selected surgical groups (j). The results of the 20 strata are then summed up.

The first part of the equation, which estimates the hospitalization costs, has four parameters:

– the PWI-related extra postoperative bed days (ΔL),
– the DRG cost weight (c_{wij}),
– an additional cost weight for the extra costs of a wound infection (c_{inf}),
– the overhead costs (P) that amount on average to 250 US$ per day.

The second part of the equation assesses the size of the sick pay for patients under 70 years who still have a relation to the working market:

– the fraction of the Danish population who had a job was of 79·3% in 1992 (E_A), corrected for unemployment and all types of pensions [27].
– sick pay (S) was 52·5 US$ per day (1993), 7 days a week. It was defined as the average between 90% of the minimum wage and the ceiling limit.
– 24 (20%) out of 117 cases aged 16–70 years, received social sick pay due to a prolonged sick leave (Table 2). This was only the case for 9·5% of the controls. Thus the additional risk (K) was 10·5% for having prolonged sick leave if the patient was a case.
– the mean postoperative sick leave (F).
– 80% of the potential jobholders did receive at least sick pay for the POW-related extra bed days in hospital (ΔL*0·8).
– the fraction of citizens in the municipality of Frederiksberg who had a job at the time of this investigation (E_P) was 73% in 1986. The number has been corrected for unemployment and pensions [28].

The two parts of the equation are then multiplied with the number of surgical interventions (A_{ij}), and with the yearly cumulative incidence of PWI (I_{ij}) in every stratum.

Table 3 shows the total data for the ten operations in Denmark for 1991. The following columns show the estimated PWI-related extra bed days, and the DRG-cost weights. Surveillance is voluntary in Denmark, but at least 66% of the departments claim to be recording infections [29]. From the National Health

Table 4. *Sensitivity analysis using the cost model showed in Figure 2. The premises for the model are described in Table 2*

Cost weight utilized*	Extra postoperative bed days % of reference	Estimated sick pay US$	Estimated hospital costs US$	Estimated total costs US$
$c_{wij}*c_{inf}$	100	1765236	16707573	18472809
	75	1765236	12992218	14757454
$(c_{wij}*c_{inf})/2$	100	1765236	10793651	12558887
	75	1765236	8095239	9860475
all outliers: $c_w = 1{\cdot}2$	100	1765236	7223193	8988429

* c_{wij}, DRG based cost weight for stratum ij; c_{inf}, DRG based additional cost weight for postoperative infection.

Register it can be calculated that 177885 patients would have been included in the infection registration if all hospitals had had such a registration. Twenty-nine percent of these patients belonged to the selected ten surgery groups. The cumulative incidences of PWI, and the extra bed days were sentinel data.

Results of a sensitivity analysis are shown in Table 4. Two cost weights are used, either $c_{wij}*c_{inf}$ or the mean values $(c_{wij}*c_{inf})/2$. Maximum cost weights might be justified because PWI delays wound healing and can lead to reoperation and the extra use of medicines. This is the view taken in the Norwegian model for DRG. The model predicts the total PWI related costs to be 18·5 million US$ per year, corresponding to 0·5% of the total hospital costs [30]. The social expenditure amounts to 9·5% of the predicted total costs. However it is perfectly reasonable to envisage an alternative where the extra costs for an infected patient are less than those for the primary uncomplicated intervention which would reduce the total PWI related hospitalization costs to 12·6 million US$ per year. The model uses a value for the prolonged sick leave (F) of 200 days, corresponding to the actual value in this intervention. An increase or a decrease of this factor by 100 days will change the total budget by 3·4%.

For the fraction of the patients for whom the stay in hospital exceeds an predefined upper limit (day outlier threshhold), it can be argued that only overhead and care costs should be included ($c_w = 1{\cdot}2$)[24]. In our study one third of the total PWI related bed days belong to this category. The last line in Table 4 shows the estimated costs if all extra postoperative bed days were calculated as outlier days. This value will then clearly underestimate the estimated costs.

The second column of Table 4 shows the predicted effect of reducing the PWI-related extra bed days by 25%. The model does not consider that costs saved in the hospital might be transferred to primary health care and to the social sector.

If we look at the estimated PWI related total costs in proportion to the annual number of operations in Denmark for the ten surgery groups, Figure 2 shows the relative expenses compared to the relative activity. PWI following surgery of the colon comprises 25% of the estimated extra costs. Though these only represent 10% of the activity, they are the most resource demanding procedures of the ten if a wound becomes infected. The estimated costs from PWI following amputations depend on the age of the patient. A few PWI will result in high costs

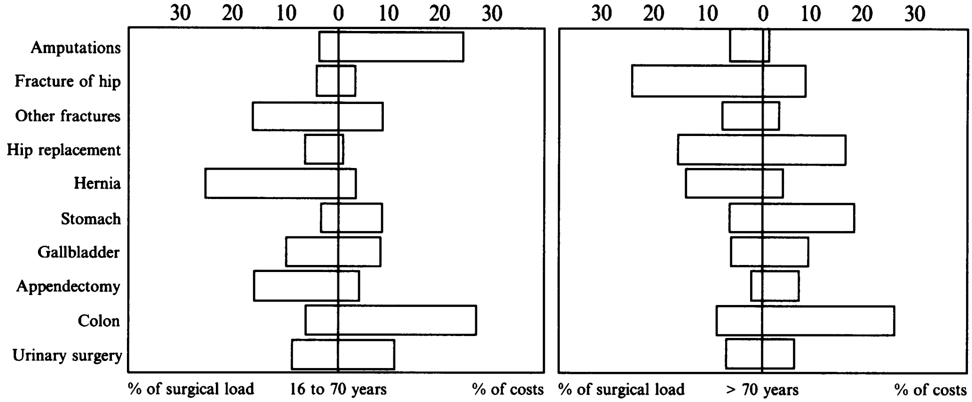

Fig. 2. The relative estimated costs for postoperative wound infections compared to the relative load for ten selected surgical interventions.

for the younger group of patients. The procedure is more common in older people but the relative costs are lower. Overall PWI following abdominal operations seem to be more costly than the selected orthopaedic types of intervention.

DISCUSSION

Other investigations [13,31,32] as well as an earlier study based on the total material from the hospital of Frederiksberg [5] showed that PWI leads to a prolonged hospitalization. Only by measuring the share of the direct costs derived from PWI, objective measurements can be given as to how much PWI adds to the negative outcome. Hospital costs can not be isolated from direct costs derived from the primary sector and the social security system, as well as from indirect and intangible costs added to the society and the patient. The aim of this study was narrower. We wanted to see if registers can substitute for more resource demanding investigations and thus can be a practicable method of easy access to information of major relevant costs. The conclusion is that the registers were not developed for this purpose, and too many resources had to be used finding information that were not on EDP. Direct estimations of costs was not possible in this study because of the historical prospective design.

Since variable costs (equivalent to direct marginal costs) equals total costs minus fixed costs, the optimal marginal analyses should exclude the fixed portion. Because we wanted to look at the total resources, and not just the funds that would be freed to alternative use if PWI was prevented, we have shown the actual total costs including the marginal considerations. The model incorporates the current data from an infection registration system in a sample of Danish hospitals. The figures are also compatible with the national surgical activity. The estimated costs of PWI are based on actual activity data from all surgical departments in Denmark. The model is only the first step in the direction [16] of predicting where the most costly PWI will occur. Information thus obtained will provide the rational considerations behind priority based prevention.

The estimated hospital costs are predicted to amount to 0·5% of the total recurrent costs. The predictions, based on the actual surgical activity for the ten selected intervention groups, is less than the estimates based on average numbers of PWI-related extra bed days and PWI incidences [1,2]. An American study which included 51 matched case-control pairs, found an increase in the mean hospital bill if the patient was an infected case [33]. For 17 patients with PWI after cardiac surgery, six were matched to controls, and the increase in the average costs for those infected was 88% [34]. A Canadian model including both direct and indirect costs as well as costs for extra days at home for infected patients was based on average figures and statistics from other studies [35]. By using their model on our material with the mean values of the PWI incidence and bed days, we estimate the hospital costs as 13·5 million US$. This is right between the estimates using the two different values of the cost weights in the sensitivity analysis shown in Table 4. The use of the two different cost weights gives an average bed day cost for the ten surgical groups which is respectively 90% and 140% of the national average for all beds. While surgical beds are more expensive than medical beds, our model can be expected to give the right order of magnitude of the estimated costs. On the other hand the longer the duration of the postoperative stay the more problematic it might be to use the full value of the cost weights. Detailed analysis are needed to elucidate to what extend a correction factor could be introduced [36].

There are several reasons why the model is expected to underestimate the total costs. Firstly while only the 10 selected operations are included in the model, it only gives the estimated costs of approximately half of the expected PWI. Secondly if a patient dies early from the infection, he contributes very little to the PWI related costs. Thirdly not all of the infections will be captured in the registration system. We know from a follow up on this material [37] that 19% of the infections were not registered. Estimates of the incidence therefore relies on a valid registration.

An important difference between the Danish public health care system and the US system, is that in the former, hospitals are not allowed to make an economic profit. In Denmark prevention of infections might save money for medicine, food and equipment, but the departments do not get paid extra money if they treat an extra patient as a result of a prevention exercise. By preventing PWI society gains an increased effectiveness within the hospital system. This might appear to be more expensive for the hospital and thus economically beneficial for the primary health and social sectors.

There are two other factors that have to be borne in mind. Not all PWI can in reality be prevented [38], and establishing an effective prevention system is resource demanding [39].

This study showed that patients with a PWI had a higher likelihood of involvement with the social security system afterwards. However the model clearly underestimates the derived total costs. It was not possible to obtain statistics on the utilization of home care, and short time sick leave was not recorded. Similarly data on the value of the time and money expended by the patients and their relatives are lacking. Neither are the social and health related consequences included in the calculations. This type of data is now being collected in a follow up study in which we ask the patients directly to provide this information instead of deriving it from registers. We plan to reevaluate and expand our model in the light of future results.

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