Nosocomial Pneumonia: A Cost-of-Illness Analysis

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Abstract

Background: We investigated incremental cost of nosocomial pneumonia (NP) from the perspective of a hospital and health insurance funds.

Patients and Methods: The incremental cost was determined by calculating total costs for pneumonia patients and controls using prospective and retrospective matched-pairs analysis with 29 and 37 matched pairs, respectively.

Results: Compared to controls, patients who developed pneumonia had to be on artificial ventilation 5 days longer, needed markedly more intensive care with 6.55 additional days in intensive care. Excess cost per pneumonia patient amounted to DM 14,606 (95% CI: DM 5,285–23,927) from the hospital's perspective and to DM 7,988 (95% CI: DM 5,281–10,894) according to statutory insurance charges. According to the retrospective analysis carried out on the neurosurgical and neurological intensive care wards, pneumonia patients were ventilated 5 days longer than patients without pneumonia, needed more intensive care over 30 days and had an additional 14.03 days of intensive care and 10.14 more days in hospital. Excess cost per patient was DM 29,610 (95% CI: DM 23,054–36,174) from the hospital's perspective and DM 18,000 (95% CI: 14,885–21,020) according to the statutory insurance criteria.

Conclusion: The study gives insight into the structure of incremental cost caused by NP and shows that based on a conservative cost calculation the incremental cost per NP patient is higher for the hospital than for health insurance funds which indicates a significant financial deficit for the hospital. Antibiotics and microbiology together only contribute 6.8% to incremental cost. Therefore in a cost saving initiative their close relationship to length of hospitalization must be considered.

Key Words

Nosocomial pneumonia · Incremental cost of hospital-acquired infections · Cost-of-illness analysis

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Introduction

The burden and costs of hospital-acquired infections are considerable. Depending on the patient population analyzed and the methods used, nosocomial infection rates in national and international studies vary from 3.5% to 10%. In a series of international surveillance studies, pneumonia accounted for 14–20% of all nosocomial infections and was repeatedly found to be the second most frequent type of hospital-acquired infection after urinary tract infection. The US National Nosocomial Infections Surveillance System (NISS) identified six to ten episodes of nosocomial pneumonia (NP) for every 1,000 patients admitted to hospital [1–6]. The highest rates of NP occur in intensive care units (ICU). [7–10]. Patients on artificial ventilation are exposed to a three to 21-fold risk of developing pneumonia. Incidence rates of pneumonia in mechanically ventilated patients range from 9–70%. NP has the highest mortality of 24–51% associated with any nosocomial infection [11–17].

Related to 11 million hospitalizations per annum and a prevalence rate of nosocomial infections of 3.46% [6], the number of NPs in Germany may be as high as 70,000 to 90,000 per year, or even higher. NP is an important cost driver causing 4–13 additional days of hospitalization for each patient affected [11–17]. It is also an enormous burden to the individual patient with far-reaching socioeconomic consequences. In

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a prospective case-control study, *Kappstein* et al. [3] found that NP caused on average 10.3 additional days of intensive care, associated with excess costs of DM 14,253 per patient, according to insurance charges. However, patients with NP are also more demanding with respect to treatment and nursing and this is mostly not included in the cost assessment based on charges for hospital stay. *Boyce* et al. [18] came to the conclusion that in the USA, a patient with NP caused excess costs of $ 5,800 which are not covered by the standard insurance and therefore imposed on the hospital.

The aim of the present study was to assess the total direct excess costs caused by NP per patient and day in a German university hospital. For this aim, the cost of hospital stay, duration of artificial ventilation, costs of nursing, microbiological diagnostics and antibiotic treatment reflecting the total expenses charged to the hospital were compared for patients who had developed NP and their matched controls without pneumonia. To assess the financial deficit for the hospital due to NP, these total costs were compared to the costs calculated according to the statutory insurance standards.

To develop an adequate cost assessment method and to estimate the number of patients needed to achieve a significant result, in a pilot study, *Dietrich* et al. [19] examined two methods for the assessment of total cost of NP using prospective matched-pairs analysis. In one of the methods, part of the costs are calculated from the resources used and completed by the records of the hospital administration. The other method uses patient records only. Both methods resulted in similar incremental cost of approximately DM 440 per day and pneumonia patient, but differed markedly in the effort of assessment. It was found that 40 matched pairs were needed to come to significant conclusions on total costs of NP. In the present analysis, costs were calculated from patient records for days of hospitalization and average costs. Direct cost assessment was carried out for antibiotics and microbiological diagnostics and their share in total costs was calculated.

Patients and Methods

Aim and Design of the Study

The aim of the study was to assess the incremental cost per patient due to NP by comparing total costs for pneumonia patients and their matched controls.

The study was designed as a case-control study in two parts, a prospective (study 1) and a retrospective one (study 2).

The following topics were analyzed:

- additional days in the primary ICU studied
- use of antibiotics and incremental cost for antibiotics
- categories of nursing
- additional nursing efforts assessed by time-and-motion study for the financially most important interventions
- duration of artificial ventilation
- frequency of microbiological diagnostics and associated costs
- cost profile of pneumonia patients and controls (cost per patient vs day of stay in hospital)
- costs based on global per case charges
- comparison of total costs assessed from the perspective of the hospital and according to insurance charges

In the retrospective part, the additional days of hospitalization were also taken into account.

Patients

The prospective study was carried out in a neurosurgical, a neurosurgical/neurological ICU, an anasthesiological ICU and two medical ICUs. Patients were recruited from May 1998 to March 1999. In the retrospective study, patients were included if they had been admitted to one of the 2 neurosurgical wards from February 1997 to December 1998.

To be included in the analysis, patients had to be older than 16 years, have had no previous history of pneumonia and have stayed on one of the study wards for more than 2 days. Patients were excluded if they suffered from community-acquired pneumonia, had neutropenia (< 2,500 leukocytes), HIV infection or if they were intravenous drug users.

NP was diagnosed according to the criteria of the Centers for Disease Control and Prevention (CDC), Atlanta [1].

Each patient diagnosed with NP and included in the study was matched with a comparable patient without pneumonia. Criteria for matching were: severity of disease, age ± 15 years, primary ward, status of ventilation (studies 1 and 2), immunosuppression (caused e.g. by corticosteroid therapy or diabetes mellitus), gender and duration of hospital stay prior to recruitment. Patients included as controls had to have stayed on the study ward for at least as many days as the patient had stayed before developing pneumonia (studies 1 and 2).

Methods

All data of the prospective and retrospective study were recorded on forms which were developed by the Pharmacoeconomic Working Group of the Institute for Environmental Medicine and Hospital Epidemiology of the University Hospital Freiburg, Germany.

Documentation was divided into a clinical and an economic part and carried out by specially trained study nurses of the Center for Clinical Studies of the University Hospital. For the prospective analysis, patients admitted consecutively to the study wards were examined for inclusion according to the criteria mentioned above and were then identified as pneumonia patients or potential controls.

In the prospective study, patients were followed continuously as long as they stayed on the primary study ward with a limit of a maximum of 30 days. Documentation was stopped when patients were transferred to another ward or hospital or were released from the hospital. Patients who died on the primary study ward were excluded from analysis.

In the retrospective analysis, follow-up data were not limited to the days spent on the primary study ward but extended to the time after patients were transferred to a general ward of the clinic. Patients were followed continuously until they were released from the hospital, transferred to another hospital or died.

All resources consumed for diagnosis, treatment, nursing and hospital stay, including materials and personnel, were recorded from tables of the finance division of the clinic. In addition, costs were calculated according to statutory insurance criteria.

Costs for antibiotics were directly documented from patient records. The costs for microbiological diagnostics were derived from the invoice lists of the respective institutions.

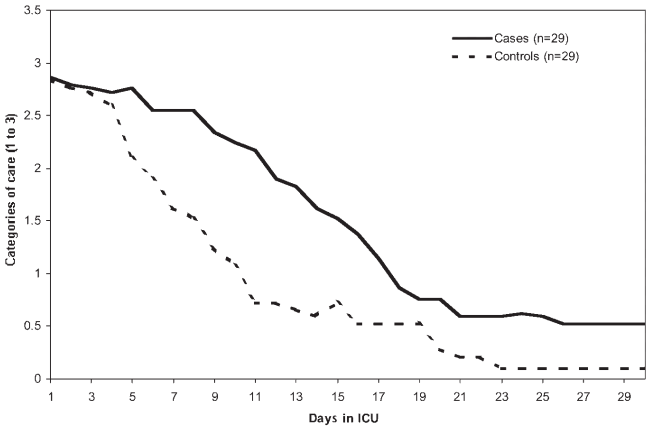

Figure 1. Categories of care in the prospective study.

Statistics

Differences in length of stay and the other parameters between cases and controls were first computed for each matched pair. Means and SD were calculated for the so-obtained differences. 95% CIs using the normal distribution are given as measure of the precision of the estimates. Student's t-test for paired observations was used to test for statistical significance at the 5% level.

Further details of the study design will be published separately.

Results

Prospective Study

A total of 188 patients admitted to one of the study wards from May 1998 and March 1999 was examined for participation and 114 were included. Of these, 48 (32 men, 16 women) were pneumonia patients and 66 (30 men, 33 women) were controls. Half of the patients were admitted for neurological disease, and 60 % of them were in neurosurgical or neurological intensive care units. Patients admitted for trauma (11 of 16), for gastrointestinal disorders (three of five) or for neurological diseases (26 of 60) had the highest rates of NP. 31 of the 48 pneumonia patients (64.6%) were on artificial ventilation when admitted to the study ward. Matched controls without pneumonia were found for 15 of the 17 pneumonia patients who were not on artificial ventilation upon admission and for 14 of the 31 ventilated patients. Thus, a total of 29 matched pairs were available for evaluation. The average age of the pneumonia patients was 59.4 years, of the controls 57.5 years.

One of the control patients stayed on the intensive care ward longer than the 30 days of the study period. The other 28 patients were transferred to a normal ward or released from hospital earlier. In pneumonia patients, follow-up on the primary ward was finished by the study end in five cases and all the others were discharged from hospital or transferred to another ward or hospital earlier.

Pneumonia patients and controls were comparable with respect to immunosuppression (4/29 vs 5/29, respectively) and to previous hospitalization for more than 7 days (4/29 vs 4/29).

Disease severity associated with the risk for early NP according to the *Kropec* score I was 13.5 and 13.2 for patients and their matched controls, respectively; *Kropec* score II was 34.1 for pneumonia patients and 30.4 for their controls [20].

In the matched-pairs group, pneumonia had been diagnosed on average 4.28 days after admission and in the total pneumonia group after 4.94 days. The respective figures ranged from 2.3 days for patients in the medical ICU and 5.9 days in the neurosurgical unit. On average, pneumonia had resolved after 16 days (end of antibiotic treatment).

Beginning at day 5 of intensive care, the categories of care were markedly different in pneumonia patients and controls and this difference was consistent throughout the study period (Figure 1).

NP was associated with a significant prolongation of stay in the ICU (on average 16.4 days ; CI: 13.60–19.22 vs 9.83; CI: 7.44–12.22, total intensive care days for pneumonia patients and matched controls, respectively). The highest excess of length of stay of 12.78 additional intensive care days was found for patients cared for on the neurosurgical ward. Pneumonia patients being ventilated when admitted to the study ward were longer in intensive care than those not ventilated at the beginning (7.9 vs 5.3 additional days). Considering the total group of pneumonia patients included in the study, the differences between ventilated and non-ventilated patients were even more pronounced with 15.5 vs 8.2 additional days in intensive care.

On average, patients with pneumonia were transferred from intensive care to a normal ward on day 16 and patients without pneumonia on day 10.

Administration records revealed that NP was associated with 7.4 (95% CI: 2.7–17.5) additional days in hospital per patient.

Additional nosocomial infections were found in three of the 29 pneumonia patients (two urinary tract infections, one meningitis) and in five of the matched controls (four urinary tract infections, one meningitis). In the total group of 114 prospectively assessed patients, five of the patients with NP (three urinary tract infections, two meningitis) and eight patients of the control group (seven urinary tract infections, one meningitis) had additional nosocomial infections.

Total Cost Analysis

Total expenses for patients with and without pneumonia are shown in figure 2. The average excess cost per pneumonia patient was DM 14,606 (95% CI: DM 5,285–23,929).

From the perspective of statutory health insurance funds, excess costs amounted to DM 7,988 (95% CI: DM 5,281–10,694) per patient with NP. Total average costs cov-

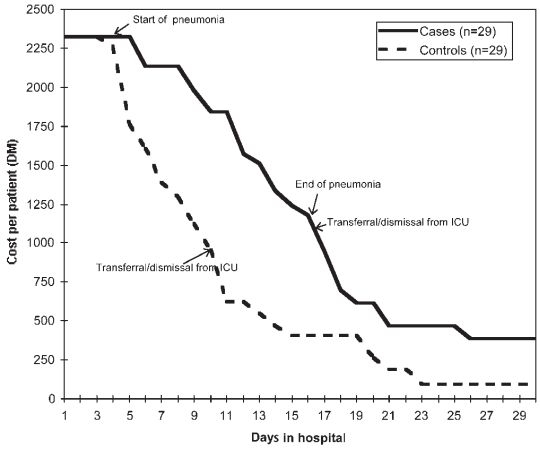

Figure 2. Cost of illness from the perspective of the hospital in the prospective study.

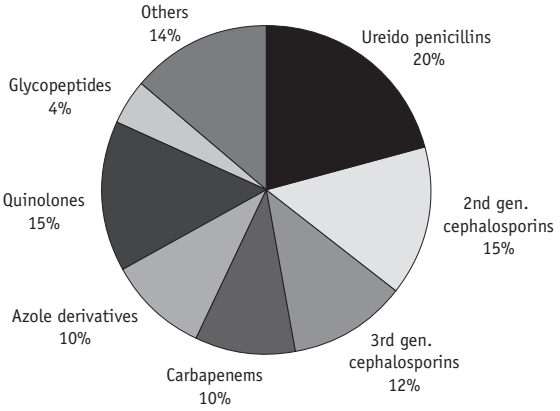

Figure 4. Antibiotics prescribed in the prospective study.

ered by the statutory insurance were DM 36,443 for patients who developed NP and DM 28,456 for patients without pneumonia.

Total costs borne by the hospital and insurance charges clearly differed, particularly between days 5 and 17 of hospitalization.

Accordingly, extra resources used in intensive care for each pneumonia patient surmounted the excess costs covered by the insurance by DM 6,618. The most marked differences between excess costs calculated from the hospital's point of view and those covered by statutory insurance funds were found between days 5 and 17 (Figure 3). The real deficit to be covered by the hospital may be even higher.

Expenses for Antibiotics

Patients who developed NP consumed more antibiotics than controls during intensive care with 2.47 vs 1.22 daily doses and costs of DM 44.42 vs DM 21.87, respectively. Total excess costs for antibiotics per pneumonia patient amounted to DM 500 (95% CI: DM 105–896) which is 3.4% of the total excess costs related to pneumonia. Excess costs for antibiotics markedly differed between initially ventilated and non-ventilated patients (DM 636 vs DM 374) and female and male patients (DM 857 vs DM 168). Highest excess costs for antibiotics of DM 918 per patient were found in the neurosurgical ICU and the lowest of DM 170 in the neurosurgical/neurological ward. Patients who had developed pneumonia on one of the medical ICUs had caused even lower costs for antibiotics (DM 419) than patients who had remained free of pneumonia. The patterns of antibiotic use are shown in figure 4.

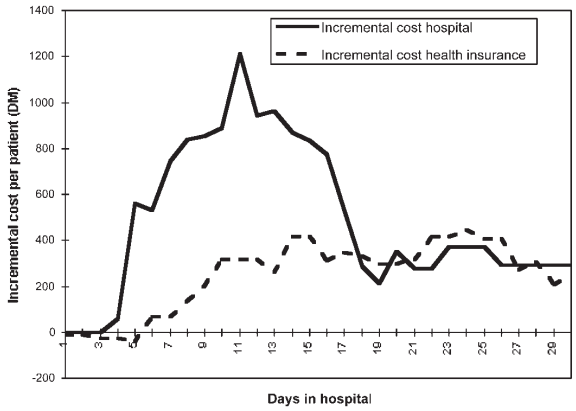

Figure 3. Incremental cost of illness from the perspective of the hospital and the health insurance funds in the prospective study.

Microbiological Diagnostics

Diagnostic measures for identification of the causative organisms and sensitivity testing were taken more frequently in the pneumonia group than in controls with 456 of the total 688 tests (66.3%) in 26 of the 29 pneumonia patients and 232 (33.7%) in 18 of 29 controls. Specimens were taken by aspiration in 146 (33%) and 86 (37.1%) of the respective groups, sputum and tracheal secretions in 135 (29%) and 60 (25.9%), respectively.

Pathogens were identified in 20 of the 29 pneumonia patients and in 12 of the control patients. The spectrum of pathogens is listed in table 1.

The average cost for microbiological tests was DM 37.04 per pneumonia patient and day and DM 20.85 per control and day. Total excess costs for pneumonia patient in intensive care amounted to DM 478 (95% CI: DM 50–906) with average total costs of DM 1,093 and DM 615, respectively.

Retrospective Analysis

Of the 435 patients admitted to the neurosurgical and neurosurgical/neurological ICUs studied, 89 (45 with and 44

without NP) were recruited for analysis. Matched controls were found for 37 pneumonia patients. The average age of the pneumonia patients was 63.1 years and of the controls 62.3 years. 19 of the matched pairs were female and 18 male. Most of the patients (94.6%) were admitted for neurological disease; 54% were on the neurosurgical und 46% on the neurological wards. Immunosuppression was present in three each of the pneumonia and control patients. Four of 37 each had been hospitalized for more than 7 days before. *Kropec* scores for early or late pneumonia were comparable with 10.41 vs 10.11 and 29.76 vs 19.70 for the respective pneumonia and control groups.

Two of the control patients and 17 of the pneumonia patients were in intensive care longer than the 30 days of study.

14 of the 37 matched pairs were on artificial ventilation at admission. The duration of ventilation was longer in pneumonia patients (mean 6.4 days; range 2–9 days) than in controls (mean 1.3 days; range 2–4 days).

NP was diagnosed 3.3 days after admission (with variation from 2.9 to 4.6 days on the various wards); 3.14 days after admission for ventilated and 3.39 days for non-ventilated patients. Pathogens isolated are listed in table 2. On average, pneumonia had resolved on day 17 (end of antibiotic treatment).

Categories of nursing clearly differed between days 3 and 15 in pneumonia patients and controls.

Intensive care was significantly longer in pneumonia patients (21.43 days; CI: 18.69–24.17 vs 7.41 days; CI: 6.18–8.64) and total hospitalization time was 22.76 days; CI: 19.98–25.54 vs 12.62 days; CI: 9.60–15.64.

Incremental costs per patient were DM 29,610 (95% CI: DM 23,054–36,174) from the perspective of the hospital and DM 18,000 (95% CI: 14,885–21,020) from the perspective of the statutory insurance criteria. Additional costs for antibiotics and microbiological diagnostics were DM 1,042 (95% CI: DM 718–1,367) and DM 776 (95% CI: DM 444–1,107), respectively.

Table 1
Microorganisms isolated in the prospective study.

	Pneumonia cases n=29	Controls n=29	Total n=58	Difference
Acinetobacter baumannii	7	1	8	6
Enterococci	3	4	7	-1
Escherichia coli	3	1	4	2
Haemophilus influenzae	4	0	4	4
Proteus spp.	2	3	5	-1
Staphylococcus aureus	4	4	8	0
Other staphylococci	11	6	17	5
Streptococci	4	2	6	2
Other bacteria	17	8	25	9
Candida albicans	8	5	13	3
Other fungi	0	5	5	-5
Total	63	39	102	24

Discussion

The present study was performed to assess the total direct excess cost associated with NP. The cost-of-illness analysis included the additional length of stay in intensive care, duration of artificial ventilation, additional nursing efforts, prolongation of total stay in hospital and expenses for antibiotic treatment and microbiological diagnosis.

The study provided complex information on the excess cost due to NP not available from previous studies with similar aims [11, 15, 21–27]. In addition, the total expenses for the hospital were compared to the cost reimbursed by statutory insurance funds.

The study was designed in two parts, a prospective and a retrospective one. The retrospective approach was chosen in addition to the prospective one as it offered many advantages in practicability; the number of potential patients was bigger and it was therefore easier to find matched pairs of patients to be included in the study. The matching criteria could be enlarged by three aspects and the whole stay of a patient in hospital was documented. In the prospective study part, patients often could not be traced after transferal to other stations.

The application of strict matching criteria as used in the analysis may have led to the exclusion of certain patient groups with an extremely high risk of NP, for whom a matching partner was not found.

Table 2
Microorganisms isolated in the retrospective study.

	Pneumonia cases n=37	Controls n=37	Total n=74	Difference
Acinetobacter baumannii	7	2	9	5
Enterococci	12	0	12	12
Escherichia coli	6	4	10	2
Haemophilus influenzae	8	0	8	8
Klebsiella pneumoniae	11	0	11	11
Staphylococcus aureus	9	3	12	6
Other staphylococci	13	3	16	10
Streptococci	11	2	13	9
Other bacteria	35	1	36	34
Candida albicans	14	0	14	14
Other fungi	17	1	18	16
Total	143	16	159	127

However, taking into account several important factors which influence the length of stay and costs as well as using the time to infection as a matching criterion facilitated comparison of the two groups of cases and controls and led to valid results.

Additional days in intensive care of 6.6 days for all matched pneumonia patients and 7.9 days for ventilated patients developing pneumonia, as assessed in the prospective study, compare well with the studies by *Kappstein* et al. [17] and *Baker* et al. [23].

The 14.0 additional intensive care days found in the retrospective study are similar to 14.5 days found by *Girou* et al. [27] who also studied a patient cohort with neurological problems in almost half of the patients. This points to the high risk and severity of NP associated with neurological/neurosurgical patients [28]. The prolongation of the total hospitalization time by 10.1 days is again compatible with findings of other investigators [22, 24]. However, taking into consideration that the study period was limited to 30 days, the real time in hospital according to administration records was even higher with 19.3 more days for the pneumonia group.

Excess time in hospital was only 7.4 days in the prospective analysis. This may be due to differences in patient populations and also to very long hospitalization times (more than 70 days) in two control patients of the prospective study.

On the medical intensive care ward, only four matched pairs were available for analysis, and short intensive care in one pneumonia patient and very long intensive care in the control may have confounded the mean figures, which resulted in a smaller number of intensive care days in pneumonia patients than in controls.

In the retrospective analysis, patients who had died were not excluded from analysis, in order to assess possible influences on hospital stay and costs. However, with four and three fatalities in the control and pneumonia groups, respectively, no differences were found when costs were calculated with or without inclusion of these cases. Further studies with a greater number of patients will be necessary to address this question.

The cost profile shows clearly increasing costs from days 3 to 5 onwards in case of NP and this parallels the start of the infection.

Costs assessed in the prospective and retrospective analysis differed. It is to be assumed that the patient cohort of neurosurgical and neurological intensive care patients is responsible for the markedly higher excess cost of DM 29,614 vs DM 14,600 in the retrospective compared to the prospective analysis. Expenses for the hospital which amounted to excess costs of DM 6,618 in the prospective and to DM 11,610 in the retrospective analysis may be even higher and the differences on the basis of insurance charges larger. The deficit for the hospital assessed by *Boyce* et al. [18] for US hospitals is in a similar range with $ 5,800 per patient.

Expenses for antibiotics were twice as high in pneumonia patients compared to the matched controls in the prospective study and four times higher in the retrospective analysis. However, the relative share in total costs was low at 3.4% and 3.5% in the prospective and retrospective analysis, respectively. The profile of antibiotic use allows some conclusions on the prescribing habits with regard to second generation cephalosporins and nitroimidazoles used at the beginning of pneumonia and azole derivatives, carbapenems and quinolones preferably used as reserve antibiotics.

Expenses for microbiological diagnosis were also only a minor component of the total cost. There are no comparable data from other cost-of-illness studies. However, the importance of identifying the pathogen and thus allowing selective treatment in NP cannot be overemphasized for this critically ill patient group, with all methodological limitations in mind which make multiple investigations necessary to come to a valid conclusion on the etiological agent [29].

The spectrum of pathogens deemed responsible for nosocomial pneumonia in this analysis is similar to that of other investigators [30]. *Acinetobacter baumannii* was isolated frequently due to an outbreak lasting from October 1997 to October 1998 in the ICUs of the neurological center of the hospital [31].

In summary, NP is an important cost driver. Patients who develop pneumonia need more days in intensive care and more overall days in hospital. Moreover, pneumonia patients need more personnel time for nursing and medical interventions and cause additional costs for antibiotics and diagnostic tests. Antibiotics and microbiological tests are only small components, each amounting to less than 5% of the total excess cost due to NP. Costs are not covered by the statutory insurance and a considerable part of the costs is imposed on the hospital.

Preventive measures to reduce the number of nosocomial infections by initiating and improving infection surveillance programs and intensifying the collaboration between clinicians and those working in hospital hygiene and clinical microbiology as well as optimizing antibiotic use are the most promising approach to cost containment.

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