Hospitalization Among Diabetic Children and Adolescents and the General Population in Germany

ANDREA ICKS, MD, MPH1
JOACHIM ROSENBAUER, MD, DIPL MATH1
REINHARD W. HOLL, MD2
MATTHIAS GRABERT, PHD3

WOLFGANG RATHMANN, MD, MSPH1
GUIDO GIANI, PHD1
ON BEHALF OF THE GERMAN WORKING GROUP FOR PEDIATRIC DIABETOLOGY

OBJECTIVE — To compare hospitalization in a multicenter-based cohort of diabetic children and adolescents (aged 1–19 years) in Germany with that of the general population.

RESEARCH DESIGN AND METHODS — Based on standardized documentation, hospital stays after manifestation were ascertained in diabetic subjects 1–19 years of age in 1997. Hospitalization data in the general German population were derived from official statistics. Incidence rates and numbers of hospital days were estimated. Ratios of hospitalization incidences and numbers of hospital days between the diabetic and the general population were calculated. Costs for hospital care in the German diabetic population in 1997 were determined.

RESULTS — A total of 5,874 patients came from 61 pediatric centers (52% male, age [mean ± SD] 12.2 ± 4.3 years, diabetes duration 4.6 ± 4.4 years). Hospitalization incidence rates and hospital days per person-year (95% CI) were 0.27 (0.25–0.29) and 1.80 (1.73–1.84) in the diabetic population and 0.0948 (0.0946–0.0949) and 0.6416 (0.6412–0.6420) in the general population. The standardized ratio of hospital incidences was 3.1 (2.9–3.2), and the ratio of numbers of hospital days was 2.8 (2.7–2.9). Costs for hospital care after manifestation were estimated to be $506 (U.S. dollars) per person-year and $12.4 million in the whole German diabetic population aged 1–19 years in 1997; including hospital stays at diabetes onset, total annual costs were $24 million ($970 per person-year).

CONCLUSIONS — Diabetic children and adolescents in Germany had an approximately three times higher hospitalization risk and three times more hospital days than the age-matched general population. Including hospitalization at diabetes onset, the annual costs of hospital care for the German diabetic population aged 1–19 years amounted to ~1% of all costs for hospital care in this age-group. Thus, costs were largely overproportional (diabetes prevalence 0.1%).


Hospitalization in children and adolescents with diabetes is associated with a high individual burden and high social costs (1–5). In the U.S., diabetes in childhood was 1 of the 10 leading causes of preventable hospitalization in individuals aged <18 years of age (6). Hospitalization results in high expenditures, amounting to 63–80% of total direct costs for type 1 diabetes (5). Reducing hospitalization is a main goal in the structured treatment of childhood diabetes, and it is a major outcome indicator in diabetes quality management (7,8).

There is a large variation in hospitalization rates and length of stays between countries and different time periods, probably due to differences between health care systems. In northern European countries, hospitalization rates among diabetic as well as nondiabetic children were higher than those in the U.S. (9–11). In Germany, the mean length of hospital stays in the general population decreased from 20 to 11 days between 1980 and 1997 (12), probably as a result of both health care politics and changes in disease management policies. Therefore, the relative hospitalization risk for diabetic children and adolescents compared with the general population may be a useful parameter to describe the excess risk of hospitalization due to diabetes. However, little information is available about this outcome in children and adolescents with diabetes, especially from large populations. Furthermore, data on costs for hospital inpatient care in this patient group are limited.

The aim of the present study was to estimate the relative hospitalization risks and hospital days in a large cohort of children and adolescents between 1 and <20 years of age with diabetes in comparison with the general German population of the same age. In addition, we estimated the annual cost of hospital care per person-year in the diabetic population 1–19 years of age and the total annual cost of hospital care in 1997 for this group in Germany.

RESEARCH DESIGN AND METHODS

Diabetic patients

Diabetic children and adolescents were consecutively recruited in pediatric departments of university and general hospitals in Germany. These centers are members of the German Working Group for Pediatric Diabetology. For the purpose of quality management, a computer-based program for the continuous documentation of treatment processes and outcomes of the diabetic patients was developed at the Division of Applied In-
Hospitalization in childhood diabetes

Information Technology at Ulm University (14), which is actually used by ~80 centers. Of these departments, 61 decided to participate in the present analysis, representing ~15% of all pediatric departments in Germany (13). The number of annually treated diabetic patients per clinic ranged from 20 to >200. Participating centers transmitted anonymous data from all of their diabetic patients, documented from the time of initiating treatment, for central validation and analysis. In 1997, 5,874 patients between 1 and 19 years of age were documented, representing about one-fourth of children and adolescents with diabetes of this age-group in Germany (15).

General population
Information on the German population between 1 and 19 years of age was derived from the national statistic registry (National Office for Statistics). In 1997, 16,850,132 inhabitants in this age-group were registered in Germany.

Data assessment
Diabetic patients. Sex, date of birth, and date of diabetes diagnosis were available for all subjects. For all patients treated in the participating clinics, hospitalizations were prospectively documented; documentation included the dates of admission and discharge and the reason for admission (coded by the treating diabetologist in five categories: diabetes onset, metabolic control and education, severe hypoglycemia, acute hyperglycemia or diabetic ketoacidosis, and “other reason”). An inpatient hospital stay was considered if there was at least one overnight stay in the clinic. All hospital stays were included, except admission at diabetes onset.

Hospitalization incidences and hospital days per person-year
Incidence rates were directly standardized, with respect to sex and age (age-groups 1 to <5, 5 to <10, 10 to <15, and 15 to <20 years of age), to the general German population. Furthermore, numbers of hospital days per person-year were estimated (crude and age- and sex-standardized).

Ratios of hospitalization incidences and numbers of hospital days per person-year
To compare hospitalization in the diabetic sample after diabetes onset with the general population, standardized ratios of hospitalization incidences and numbers of hospital days per person-year were calculated using indirect standardization with respect to age and sex (17). Furthermore, age- and sex-specific ratios were estimated. CIs (95%) were determined using normal asymptotics. Incidences and rate ratios were compared using likelihood-ratio statistics.

Hospitalization: incidences and number of hospital days per person-year
In the diabetic cohort, there were 1,330 hospital admissions and 8,781 hospital days in 1997 (without hospitalization at diabetes onset). Mean hospital stay per admission was ~7 days. Among diabetic subjects, 17.8% were hospitalized at least once in the observation period; 3.4% had more than one admission.

Cost of hospital care
Because the actual costs of hospital care were not available, cost of hospital care was calculated using the 1997 mean charges per hospital day in German hospitals (15), which was $281 (1 U.S. dollar = 1.98 Deutsche Marks [December 1999]). The charge included medical care, medication, and hospitality services.

Statistical methods
Descriptive statistics were performed for all continuous and categorical variables. Differences were tested using t tests or \( \chi^2 \) tests, where appropriate. The level of significance was 0.05.

RESULTS
Characteristics of diabetic subjects
Among the 5,874 diabetic patients between 1 and 19 years of age who were treated in 1997, 52% were male. The mean age (±SD) was 12.2 ± 4.3 years, and the mean diabetes duration was 4.6 ± 4.4 years. In total, there were 4,782 person-years under observation in 1997.

Hospitalization: incidences and number of hospital days per person-year
In the diabetic cohort, there were 1,330 hospital admissions and 8,781 hospital days in 1997 (without hospitalization at diabetes onset). Mean hospital stay per admission was ~7 days. Among diabetic subjects, 17.8% were hospitalized at least once in the observation period; 3.4% had more than one admission.

Of total admissions, 57% were due to participation in structured education or metabolic control programs, 12% were due to ketoacidosis, and 5% were due to severe hypoglycemia; 26% were attributed to other reasons, including admissions not related to diabetes.

The hospitalization rate [per person-year (95% CI)] in the diabetic cohort, standardized to the German population with respect to age and sex, was estimated to be 0.27 (0.25–0.29), and the standardized number of hospital days was estimated to be 1.80 (1.75–1.84). In the general population, hospitalization incidence was estimated to be 0.0948 (0.0946–0.0949), and the number of hospital days per person-year was 0.6416 (0.6412–0.6420). The incidences and numbers of hospital days per person-year in the diabetic population were signifi-
Ratios of hospitalization incidences and of numbers of hospital days for diabetic subjects compared with the general population

The standardized hospitalization incidence ratio for diabetic subjects compared with the general population was estimated to be 3.1 (2.9–3.2), and the standardized ratio of the numbers of hospital days per person-year was estimated to be 2.8 (2.7–2.9). Ratios of hospitalization incidences and hospital days differed with age and sex, with a significantly higher ratio in girls compared with boys ($P = 0.047$ and $P < 0.001$, respectively) and also significantly higher in pubescent children (10–15 years) than in older or younger children ($P < 0.001$)—except the hospital incidence in children aged 1 to <5 years ($P = 0.077$). Age- and sex-specific incidences and numbers of hospital days are presented in Tables 1 and 2.

**Costs of hospital care**

The cost per person-year for hospital care in 1997 was estimated to be $506 in diabetic subjects after diabetes onset and $180 in the general population. The total annual cost for hospital care in the German diabetic population 1 to <20 years of age (prevalence 0.14%; ~25,000 subjects and ~44,000 hospital days) was $12.4 million, corresponding to 0.4% of the total annual cost for hospital care in the age-matched general population in 1997 (~10.8 million hospital days).

Including hospitalization at diabetes onset (3,000 manifestations per year, mean hospital stay 13.8 days, resulting in $11.6 million), the annual cost per person-year for hospital care in the German diabetic population between 1 and 20 years of age amounted to $970. For the entire German diabetic population ages 1–19 years, the total cost was $24.0 million, which corresponded to 0.8% of the total costs for hospital care for children and adolescents of the same age-group in Germany in 1997.

**CONCLUSIONS** — The present study is the first to show that children and adolescents between 1 and <20 years of age in Germany had three times more hospital admissions and three times more hospital days per person-year compared with the general population. Estimating relative hospitalization in the diabetic population compared with the general population is useful be-

<table>
<thead>
<tr>
<th>Sex</th>
<th>Hospitalization incidence rates (95% CI) per person-year in the diabetic study population</th>
<th>Hospital rate ratios (95% CI) in diabetic subjects compared with the general population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>0.26 (0.24–0.29)</td>
<td>2.8 (2.6–3.0)</td>
</tr>
<tr>
<td>Female</td>
<td>0.29 (0.27–0.32)</td>
<td>3.1 (2.9–3.4)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Age-groups (years)</th>
<th>Hospitalization incidence rates (95% CI) per person-year in the diabetic study population</th>
<th>Hospital rate ratios (95% CI) in diabetic subjects compared with the general population</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 to &lt;5</td>
<td>0.27 (0.20–0.35)</td>
<td>2.4 (1.8–3.0)</td>
</tr>
<tr>
<td>5 to &lt;10</td>
<td>0.23 (0.20–0.25)</td>
<td>2.8 (2.4–3.1)</td>
</tr>
<tr>
<td>10 to &lt;15</td>
<td>0.34 (0.32–0.37)</td>
<td>4.3 (4.0–4.6)</td>
</tr>
<tr>
<td>15 to &lt;20</td>
<td>0.24 (0.22–0.27)</td>
<td>2.2 (2.0–2.4)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sex</th>
<th>Number of hospital days per person-year (95% CI)</th>
<th>Ratios of hospital days per person-year (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>1.67 (1.61–1.72)</td>
<td>2.6 (2.5–2.6)</td>
</tr>
<tr>
<td>Female</td>
<td>2.02 (1.96–2.08)</td>
<td>3.2 (3.1–3.3)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Age-groups (years)</th>
<th>Number of hospital days per person-year (95% CI)</th>
<th>Ratios of hospital days per person-year (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 to &lt;5</td>
<td>2.71 (2.40–3.04)</td>
<td>4.1 (3.7–4.7)</td>
</tr>
<tr>
<td>5 to &lt;10</td>
<td>1.48 (1.39–1.58)</td>
<td>3.0 (2.9–3.2)</td>
</tr>
<tr>
<td>10 to &lt;15</td>
<td>2.08 (1.99–2.18)</td>
<td>3.9 (3.8–4.0)</td>
</tr>
<tr>
<td>15 to &lt;20</td>
<td>1.17 (1.10–1.25)</td>
<td>1.8 (1.7–1.9)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sex</th>
<th>Number of hospital days per person-year (95% CI)</th>
<th>Ratios of hospital days per person-year (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>0.92 (0.75–1.12)</td>
<td>1.9 (1.6–2.3)</td>
</tr>
<tr>
<td>Female</td>
<td>1.43 (1.43–1.53)</td>
<td>3.6 (3.3–3.8)</td>
</tr>
<tr>
<td>5 to &lt;10</td>
<td>2.39 (2.29–2.49)</td>
<td>4.4 (4.2–4.6)</td>
</tr>
<tr>
<td>10 to &lt;15</td>
<td>2.20 (2.10–2.31)</td>
<td>2.1 (2.0–2.2)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Age-groups (years)</th>
<th>Number of hospital days per person-year (95% CI)</th>
<th>Ratios of hospital days per person-year (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 to &lt;5</td>
<td>0.027 (0.027–0.027)</td>
<td>3.0 (2.9–3.1)</td>
</tr>
<tr>
<td>5 to &lt;10</td>
<td>0.34 (0.32–0.37)</td>
<td>4.3 (4.0–4.6)</td>
</tr>
<tr>
<td>10 to &lt;15</td>
<td>0.24 (0.22–0.27)</td>
<td>2.2 (2.0–2.4)</td>
</tr>
<tr>
<td>15 to &lt;20</td>
<td>0.24 (0.22–0.27)</td>
<td>2.2 (2.0–2.4)</td>
</tr>
</tbody>
</table>
cause relative hospitalization risks are less sensitive to differences in general hospitalization rates between countries and calendar times. Ratios of hospital incidences and days in the present study were significantly higher during puberty (10 to <15 years) and in girls.

There are only a few other studies in Europe and the U.S. with respect to the hospitalization rates of diabetic children compared with the general population. In the present study, lower ratios of hospitalization rates and hospitalization days were found when compared with northern European countries in the 1980s. In Denmark, the number of hospital days was ~7- and 14-fold increased in boys and girls, respectively, in diabetic versus non-diabetic subjects aged 0–14 years (19). The relative risks for hospitalization were ~4.0–8.0 in boys and 4.0–5.0 in girls. In Finland, the number of hospital days in diabetic subjects <14 years of age with hospitalization after diabetes onset within 1 year was 10-fold increased compared with the general population (11).

The reasons for the higher relative hospitalization rates in the previous studies in European countries are unknown. A possible explanation is a general trend toward reduction of hospitalization in the past decade because of economic reasons, but also because of changes in diabetes care. For example, in the Netherlands, the mean length of a hospital stay for diabetic children and adolescents decreased from 25 to 11 days between 1980 and 1991 (20). Additionally, differences between health care systems may play a role.

Hospitalization incidences and lengths of hospital stay in the present study were higher than those reported in the U.S. and the U.K. Recently, ~0.1–0.15 hospital admissions per person-year were reported in diabetic subjects <18 years of age in the U.S. (10). In the U.K. in the early 1990s, hospital incidences in diabetic children and adolescents in the first 4 years after diabetes onset were 0.19 per person-year (21). Nevertheless, in the U.S. and in the U.K., hospitalization in general is lower than that in northern European countries and, in particular, Germany, where much effort has been undertaken to further reduce hospitalization (22). However, the rate of hospitalization in the diabetic population in the present study was lower compared with those reported in Finland and Denmark, where hospital incidences were ~0.3–0.4 per person-year (11,19).

A high proportion of hospitalization was related to participation in structured inpatient diabetes education program. Incidences of acute complications were low compared with other countries. Thus, the incidence of severe hypoglycemia leading to hospital admission was estimated to be 0.06 per person-year in the U.K. (21) and ~0.02 in Wisconsin (10). In the present study, where 3% of admissions were due to severe hypoglycemia, it is roughly estimated to be 0.01 per person-year. It is conceivable that structured diabetes education results in fewer acute complications. This effect could be shown in several trials (23–25) and population-based studies (10). Nevertheless, diabetes education does not always require inpatient hospital care; it could also be performed in specialized outpatient settings (26). However, reimbursement for hospital care in Germany actually favors inpatient education programs, although there are increasing efforts to replace these programs with outpatient care.

The estimated cost for hospital care per person-year in the diabetic study population 1–19 years of age after onset was nearly three times higher than that in the general population. By applying this finding to the diabetic German population, the annual cost of hospital care for diabetic children and adolescents aged 1–19 years without hospitalization at diabetes onset would amount to ~0.5% of the total annual costs of hospital care in the German population in this age-group in 1997; this figure would increase to ~1% when factoring in hospital admissions at diabetes manifestation. Prevalence of diabetes was only ~0.1% in this age-group; thus, there were overproportional costs in the diabetic population.

In Sweden, at the beginning of the 1990s, costs for hospital care of subjects with type 1 diabetes were ~$800 per year higher than those for the general population (2). In a Finnish study, the average annual cost for diabetes care in the first 2 years after onset in diabetic children was ~$2,800. Of this annual cost, 17% (~$475) was attributable to hospital care (4,5). Comparisons between studies are difficult, because they differ largely with respect to study design and assessment methods. In general, comparison of costs between different health care systems is limited.

Some limitations of the present analysis have to be considered. We have not performed a population-based study but a multicenter investigation in pediatric departments that offer specialized diabetes care. Therefore, the results of the study may not be representative for all children and adolescents with diabetes in Germany. Unfortunately, there is no nationwide information available about diabetic children and adolescents with diabetes. However, there is good evidence that the study population is representative for the whole German diabetic population: with respect to age distribution, the study population was similar to the whole diabetic population aged 1–19 years in Germany. Furthermore, the relative risks for hospitalization in this study were comparable with the results of a population-based study in a geographically well-defined region in Germany where a cohort was followed for up to 2.5 years after diabetes onset (27,28).

The present study was based on continuous computer-based documentation in pediatric departments that take part in a quality management initiative of the German Working Group for Pediatric Diabetes. All patients treated in these centers were included, and it can be assumed that the hospitalization documentation is considered valid, because clinics also use the documentation for administrative purposes. However, underestimation of hospitalization because of underreporting may exist. Hospitalization data in the general population were derived from official statistics that were described to be almost complete (15).

We did not exclude admissions due to diabetes from the general population data. Thus, the denominator for the relative risk estimation may be overestimated, and the relative risk may be biased toward 1, thereby yielding a more conservative estimation. However, because of the low prevalence of diabetes in this age-group, the bias is assumed to be very small.

The cost of diabetes was only roughly estimated because only the cost of hospital care was included. Data on further direct costs (e.g., those for ambulatory care or insulin) are not currently available. However, the cost for hospital care is assumed to represent a large proportion of costs in pediatric diabetes care. Furthermore, because data about costs in pediatric diabetes care are limited, the results of
the present study are expected to be important.

In conclusion, hospitalization in children and adolescents with diabetes in specialized pediatric diabetes care was substantially increased compared with the general population. Expenditures for hospital care in this population were high in relation to the low prevalence of diabete in children and adolescents. Ongoing efforts are undertaken to reduce the high hospitalization rate among pediatric diabetic patients. A repetition of the present study could evaluate potential successes. Reduction of hospitalization rates and the cost of diabetes care are of rising importance because of increasing health care expenditures and incidence rates in diabetes during childhood in Germany and worldwide (2, 29–32).

Acknowledgments—We are grateful to the following pediatric departments that contributed data to this study: St. Franziskushospital, Ahlen (G. Friedrich); Helios-Klinikum, Aue (K. Predicow); Kinderklinik Zentralklinikum, Augsburg (M. Hauschild); Kinderklinik Lindenhof (H. Haberland) and Virchow Klinikum, Berlin (O. Kordonouri, T. Danne); Kinderzentrum Gilead, Bielefeld (F. Janssen); Kinderklinik Bonn, Bonn (N. Albers); Kinderklinik St. Jürgenstrasse, Bremen (W. Marg); Kinderklinik Allgemeines Krankenhaus, Celle (J. Zimmermann); Städtische Kinderklinik Chemnitz, Chemnitz (A. Klinghammer); Kinderklinik St. Vincenz, Coesfeld (E. Lang); Uni-Kinderklinik Dresden, Dresden (A. Naeki); Uni-Kinderklinik Erlangen, Erlangen (K. Freundl); Kinderklinik Erfurt (A. Lemmer); Uni-Kinderklinik Freiburg, Freiburg (O. Schwab); Kinderklinik am Klinikum, Fürth (K. Freundl); Kinderklinik Marienhospital, Gelsenkirchen (M. Papsch); Uni-Kinderklinik Gießen, Gießen (A. Dost, R.W. Holf); Städtische Kinderklinik, Görlitz (G. Korth); Kinderklinik Allgemeines Krankenhaus, Hagen (U. Schimmel); Altonaer Krankenhaus, Hamburg (R. Lepler, K.P. Otto); Städtische Kinderklinik Hagen (M. Bentfeld, A. Kohlhammer); Kinderklinik Jürgenspital, Hanau (W. Krill); Kinderklinik Kurtz-Krankenhaus, Hanover (A. Teller WM, Heinze E, Renner C, Schweiggert F, Teller WM, Heinze E; Quality control in health care of children and adolescents with diabetes: an external comparison in 23 centers of pediatric diabetesology. Diabet Stoffs 6:83–90, 1997

4. Simrell T, Simrell O, Sintonen H: The first two years of type 1 diabetes in children: length of the initial hospital stay affects costs but not effectiveness of care. Diabetes Care 17:1257–1263, 1994

References
Hospitalization in childhood diabetes


