TITLE

The impact of single gene and chromosomal disorders on hospital admissions of children and adolescents: a population based study.

RUNNING TITLE

Hospital admissions of children with single gene and chromosmal disorders.

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KEYWORDS

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ABSTRACT

Background

It is well recognized that genetic disease makes a significant contribution to childhood illness. Here, we present recent population data describing the impact of single gene and chromosomal disorders on hospital admissions of children and adolescents.

Methods

Hospital admissions for patients aged 0-19 years between 2000 and 2006, with a single gene or chromosomal disorder, were extracted from the Western Australian Hospital Morbidity Data System using 296 diagnosis codes identified from the International Statistical Classification of Diseases, Tenth Revision, Australian Modification. Data extracted for each patient included the number, length and cost of all admissions.

Results

Between 2000 and 2006, 14 197 admissions were identified for 3271 patients aged 0 - 19 years with single gene and chromosomal disorders, representing 2.6% of admissions and 4.3% of total hospital costs in this age group. Patients with genetic disorders had more admissions and stayed longer in hospital than patients admitted for any reason. Specific disorders associated with a high demand on hospital services included cystic fibrosis, Down syndrome, osteogenesis imperfecta, thalassemia and von Willebrands disease.

Conclusions

Children and adolescents with single gene and chromosomal disorders placed higher demands on hospital services than other patients in their age group, but were responsible for a relatively small proportion of hospital admissions and costs. These data will enable informed planning of health care services for patients with single gene and chromosomal disorders in Western Australia.

INTRODUCTION

The twentieth century saw a major shift in the profile of human health and disease from communicable to non-communicable and genetic disease, due largely to the successful introduction of antibiotic therapy and vaccination programs for infectious diseases [1, 2]. This is illustrated by data from the Great Ormond Street Hospital for Children in London, where the proportion of childhood deaths attributed to genetic disorders increased from 16.5% in 1914 to 37.5% in 1954 [3]. Similar transitions occurred in all industrialized nations and the increasing burden of genetic disease, especially in childhood, has been recognised as an area of concern since the 1970's [4].

Genetic disorders can be divided into three categories: those caused primarily by changes in a single gene; chromosomal abnormalities; and those resulting from interactions between multiple genes and the environment (complex disorders). Although single gene and chromosomal disorders are individually rare, together they affect approximately 2% of the population, with estimates suggesting an incidence of 3.8 per 1000 for chromosomal disorders and 20 per 1000 for single gene disorders [5].

Previous studies investigating the impact of genetic disease on hospital admissions found that patients with genetic conditions had more admissions, longer hospital stays and increased morbidity and mortality than patients without genetic conditions (Table 1) [2, 6-16]The landmark study in this area was published by Hall *et al.* (1978) [4] who reported that of all admissions in a pediatric hospital, 4.5% were due to clearly genetic disorders (single gene or chromosomal), 48.9% to partly genetic conditions and 46.6% to non-genetic conditions. Patients with clearly

genetic disorders had a higher mean number of admissions and stayed longer in hospital than patients without a genetic disorder [4]. More recent hospital-based studies have explored the impact of genetic disease on different types of hospital admissions, including those to emergency departments [12], intensive care/high risk units [8] and general hospital wards [11, 15]. Interestingly, most report similar data, regardless of the setting, with the proportion of childhood and adolescent admissions due to single gene or chromosomal disorders ranging from 5.0 – 11.1% (Table 1). A population-based study of hospital admissions of people aged less than 20 years also reported similar data, with 12 % of admissions in California and 9% in South Carolina due to genetic diseases and birth defects [16]. Admissions due to genetic diseases and birth defects were found to be longer and cost twice as much as those from other causes [16].

The current study assessed the admission patterns of children and adolescents with single gene and chromosomal disorders using the population-based hospital services data available in Western Australia (WA). We chose to focus on single gene and chromosomal disorders, rather than all "genetic diseases", as the distinction between genetic and non-genetic conditions has become ill defined in recent years, with evidence that even infectious disease has a genetic component [19, 20]. Single gene and chromosomal disorders are easier to define, may be severe, and the attributable fraction of their hospital needs due to their disorder is likely to be high.

WA is a state of Australia, occupies the western one-third of the Australian continent and has a population of 2.2 million, approximately 10% of the national total [17]. In 2008, 74% of the population resided in Perth, the capital city, 20% lived in regional centers and 6% were classed as living in remote locations [17]. The WA Hospital Morbidity Data System is a statutory collection of data relating to all inpatient admissions to public, private and freestanding day hospitals in WA

since 1970 and is part of the WA Data Linkage System (WALDS) [18] The WADLS is a multi-set system used for the creation, storage, update and retrieval of links between health and welfare-related data and contains health data for the historical population of recent decades (3.7 million individuals going back as far as 1966) [18].

The aims of this study were to a) investigate the impact of single gene and chromosomal disorders on the frequency and duration of hospital admissions in childhood and adolescence, with a view to informing health care service planning; b) assess the capability of the existing WA data linkage system to adequately reflect the impact of patients with single gene and chromosomal disorders on the hospital system; and c) explore whether the impact of these disorders in WA is similar to that described in other populations.

METHODS

For this study, 296 diagnosis codes specific to single gene and chromosomal disorders were identified from the International Statistical Classification of Diseases, Tenth Revision, Australian Modification (ICD-10-AM; ICD10)[21] (Supplementary Table 1). The ICD-10-AM differs from the ICD-10 in that it includes some Australian extensions and Australian-specific disease codes. The majority of ICD-10-AM diagnosis codes used in this study were identical to ICD-10 codes, except for some multi-system syndromes, which resulted in the ICD-10-AM code being mapped to the code immediately above it in the hierarchy of both classifications. Data in this study were grouped and analyzed using higher-level hierarchy classifications and as such can be compared to other studies using ICD-10.

The WA Hospital Morbidity Data System was searched electronically for any individual aged 0 – 19 years who had at least one of the selected ICD-10-AM codes recorded in the diagnosis fields between 2000 and 2006. For each of these individuals all of their linked records between 2000 and 2006 were also extracted. The data extracted for each patient included the number of admissions for the principal diagnosis; the number of all admissions; the number of same-day admissions versus overnight admissions; the mean length of stay (LOS) of overnight admissions; and the cost of all admissions for a person with a specific diagnosis.

Costs in Australian dollars (AUD) were calculated by applying Commonwealth Department of Health and Ageing year-specific average cost-weights to the Australian Refined Diagnosis-Related Group (AR-DRG) of the admission [22]. Diagnosis Related Groups (DRGs) are a patient classification scheme that relates the number and types of patients treated in a hospital to the resources required by that hospital. Each hospital separation is assigned a DRG and each DRG represents a class of patients with similar clinical conditions requiring similar hospital services. Cost-weights are allocated to DRGs on the basis of the National Hospital Data Collection, which includes hospital cost and activity data for a given financial year. Costs for 2000 - 2006 were adjusted to the reference year 2006–2007 using total health price index deflators [23] and converted from Australian to US dollars using the mean exchange rate for the 2006-2007 financial year, obtained from www.oanda.com.

Statistics describing the total number of patients, total admissions, mean LOS and cost of admissions for patients admitted for any reason between 2000 and 2006 were also extracted from the WA Hospital Morbidity Data System, and costs were calculated as for the cases.

The genetic data were examined both by type of disorder and by age group. One-year data sets were used to investigate admissions by age group to confine each patient to a single age group. The one-year data sets were then compared to all admissions in WA in that year. The age groups used were: <1 year (infancy), 2 -4 years (early childhood), 5 – 9 years (middle childhood), 10 - 14 years (late childhood/early adolescence) and 15 – 19 years (late adolescence). These five-year age groupings are commonly used in health statistics and allowed comparison of our data to publicly available health and hospital data. The <1 and 2 - 4 year age groups aimed to capture admissions during infancy versus young childhood, as it was hypothesized that combining these age groups may lead to over-simplification and loss of data.

The Department of Health of Western Australia Human Research Ethics Committee approved the use of the WA Hospital Morbidity Data collection for this study (project number 200723).

RESULTS

In total, 3271 different patients aged 0 – 19 years with a single gene or chromosomal disorder were admitted to hospital in Western Australia between 2000 and 2006 (Table 2). These patients accounted for 14 197 admissions. Metabolic disorders, chromosomal abnormalities, diseases of the blood and blood forming organs, neuromuscular disorders and skeletal disorders had the highest number of patients and admissions, and highest costs, while diseases of the circulatory and digestive systems affected very few patients.

Patients admitted to hospital with single gene or chromosomal disorders were also analyzed by age group, and the data compared to all patients admitted to hospital in WA in 2000 and 2006. Similar data were obtained for both years and 2006 data were selected as representative (Tables

3, 4). In 2006, 858 patients were hospitalized 2241 times in WA due to single gene and chromosomal conditions; accounting for 1.5% of patients aged 0 – 19 years and 2.8% of all admissions (Table 5).

The ratio of same day to overnight admissions varied with age group but was similar for patients with single gene or chromosomal disorders versus all patients, except in the 15 – 19 year age group where 70% of genetic admissions were for at least one night, compared to 51% of all admissions (Tables 3, 4). There was also some variation in the proportion of same day versus overnight admissions depending on the type of genetic disorder. For example, 75% of patients with immune disorders were admitted and discharged on the same day, compared to only 25% of patients with endocrine disorders and 21% of patients with disorders of the urinary system (Table 2).

Patients with single gene and chromosomal disorders had a higher number of admissions per patient and a longer mean LOS compared to other patients, and this was consistent over all age groups (Tables 3, 4). Correspondingly, the cost per patient and cost per admission was higher for patients with single gene and chromosomal disorders than for other patients (Tables 3, 4, 5). Interestingly, the proportion of overall patients, admissions and costs in each age groups differed between patients with single gene and chromosomal disorders and other patients, which may indicate differences in the disease and resource profile at different ages between the two groups. Overall, patients with single gene and chromosomal disorders accounted for 5.1% of the cost of hospital admissions of 0 – 19 year olds in WA in 2006 (Table 5) and 4.3% from 2000 – 2006 (Table 2).

We next examined which specific single gene and chromosomal disorders contributed most to hospital admissions and costs in WA from 2000 to 2006 (Table 6). Cystic fibrosis (CF) and Down syndrome (DS) were each responsible for 12% of admissions and accounted for 22% and 12% of the overall costs of hospital admissions of patients with single gene or chromosomal disorders. CF accounted for 68% of the costs associated with metabolic disorders and DS for 57% of those attributed to chromosomal abnormalities (shown in Table 1). The next most costly patients were those with congenital malformations (e.g. Noonan syndrome and Marfan's syndrome), osteogenesis imperfecta (OI) and von Willebrand's disease (vWD), which each accounted for approximately 4% of the costs associated with patients with single gene and chromosomal disorders.

The admission costs for patients with these disorders were also analyzed by age at admission (Table 6). The total cost of admissions associated with DS, polydactyly and spinal muscular atrophy were highest in patients less than one year of age, with a steady decline in expenditure in the older age groups. In contrast, the total costs due to CF, vWD and primary disorders of muscle (e.g. Duchenne muscular dystrophy and congenital muscular dystrophy) increased between the ages of five and 19 years. Other conditions, such as metabolic mitochondrial disorders, showed a peak in costs in early childhood, while the osteochondrodysplasias (e.g. OI) were associated with high admission costs from the ages of one to 14 years, and a decline thereafter. Changes in costs between age groups were due to either a change in the number of admissions, or the cost per admission.

DISCUSSION

Impact of single gene and chromosomal disorders on hospital admissions

Overall, 1.5% of patients aged 0 – 19 years admitted to hospital in WA in 2006 had a single gene or chromosomal disorder and these patients accounted for 2.6% of admissions and 5.1% of total hospital costs. When hospital admissions were investigated over a seven-year period (2000 – 2006), genetic conditions accounted for 3.1% of admissions and 4.3% of total costs. These data suggest that hospital admissions in WA due to single gene or chromosomal disorders in children and adolescents were relatively stable during this time. Patients with single gene and chromosomal disorders had more admissions to hospital and a greater mean LOS than patients admitted for any reason in WA in 2006, leading to higher per-admission and per-patient costs. These data are consistent with other studies (Table 1) [4, 8, 11, 16], despite differences in the population surveyed, data collection procedures and ICD coding used.

Patients with CF and DS accounted for the highest number of admissions (12% each) and highest costs (22% and 12% respectively) of patients with single gene and chromosomal disorders, which is also consistent with previously published data [4, 11]. Hall *et al.* (1978)[4] found that CF and DS were the most common clearly genetic disorders in their cohort while McCandless *et al.* (2004) [11] reported that 11% of admissions for single gene and chromosomal disorders were due to CF and 12% to chromosomal disorders. Taken together, these data suggest that in populations of primarily Caucasian heritage, CF and DS are responsible for a significant proportion of hospital admissions due to single gene and chromosomal disorders and this has remained constant over at least a 30-year period.

We also examined whether the impact of the most costly single gene and chromosomal disorders changed during childhood and adolescence (Table 3). CF and primary disorders of muscle (e.g. Duchenne Muscular Dystrophy) were associated with an increased number of admissions and associated costs as patients became older. These data are consistent with other studies [24, 25] and with the natural history of these disorders, which have a greater impact on morbidity with increasing age [26]. In contrast, admissions due to DS and polydactyly show a decreasing trend in admissions in older children and adolescents, also consistent with the course and management of these disorders [27, 28].

Our study also examined all genetic admissions to hospital in five different age groups (Table 4). Yoon *et al*. (1997) [16] found the mean cost of admissions and the proportion of total hospital costs due to genetic diseases and birth defects was highest in infants aged <1 year and decreased throughout childhood and adolescence whereas we found that the proportion of total WA hospital admissions and costs due to patients with single gene and chromosomal disorders was highest in the 2 - 4 year age group and declined thereafter (Table 5). However, Yoon *et al*. (1997) [16] included all birth defects (which are often diagnosed in the first year of life) whereas we limited birth defects to those known to be of single gene or chromosomal origin. Interestingly, although the proportion of total admissions and costs due to patients with single gene and chromosomal conditions decrease in late adolescence (15 – 19 years), the actual cost per admission and cost per patient in this age group is higher, relative to all patients, than in any other age group (2.6 fold and 5.2 fold, respectively) (Table 5). Thus, although less patients with single gene and chromosomal disorders are admitted to hospital in this older age group, those patients that are admitted place high demands on the hospital system.

To ascertain whether the decreasing number of admissions of patients with single gene and chromosomal disorders with increasing age could be explained by the death of severely affected individuals, we also investigated the death data for the patients who had selected ICD10 codes recorded in the diagnosis field. Thirteen deaths were recorded in patients aged 0 – 19 years, four in infants less than 1 year. Thus, although death would be a contributing factor to decreased hospitalizations with increasing age, it is unlikely to have had a major influence on our dataset.

Methodology and Limitations

The fact that the pattern and costs of hospital admissions of specific single gene and chromosomal disorders is consistent with other studies and the known clinical presentation of these diseases suggests that the WA hospital morbidity database is an appropriate tool to measure the impact of patients with single gene and chromosomal disorders on the hospital system in WA. Overall, however, the proportion of admissions due to patients with single gene and chromosomal disorders in our study is less than in most other studies (Table 1) [4, 8, 9, 11, 12, 15, 16]. This may be due to differences in the classification of genetic disorders, population demographics and the mode of data collection.

Classification of disorders

Our study identified only single gene and chromosomal disorders while most others identified all disorders with a genetic component, often divided into subgroups. Thus, our sample was more stringently defined than others, which may partly account for our lower estimates. For example, although Yoon *et al*. (1997) limited their dataset to mainly single gene and chromosomal disorders, they also included all birth defects, including those of multi-factorial and non-genetic origin (e.g. cleft lip and palate, fetal alcohol syndrome) [16]. However, by limiting our analyses

to single gene and chromosomal disorders we have provided information about a subgroup of potentially severe disorders to enable improved health service planning for those affected.

Population differences

Most published studies have been based in Northern [4, 7-9, 11, 14] and Latin [6, 13] America and the ethnicity of these populations is very different from WA. For example, Kumar *et al.* (2001) reported on a predominantly Hispanic and African American population in New York [9] while Yoon *et al.* (1997) reported that 40% of admissions in South Carolina were of African American patients [16]. This is reflected in the frequency of admissions due to specific conditions. For example, sickle cell diseases accounted for 27% of genetic admissions in South Carolina, compared to 1.3% of admissions due to single gene and chromosomal disorders in WA.

Mode of data collection

Most studies investigating the impact of genetic disease have done so via direct review of medical records in one or two hospitals, with only this study, Yoon *et al.* (1997) and Baird *et al.* (1988) accessing statewide data [16, 29]. Studies that used direct review may get more complete ascertainment of admissions due to single gene and chromosomal disorders for a number of reasons. Firstly, the hospitals surveyed tended to be located in large cities and are often referral centers for their region. Thus, clinicians in these hospitals may have greater exposure to and expertise at diagnosing genetic disorders compared to clinicians practicing in smaller local hospitals. As 26% of the WA population lives in rural or remote areas [17] it is possible that some children and adolescents with single gene or chromosomal disorders may not be correctly diagnosed unless they receive medical attention from a metropolitan tertiary hospital. Thus, our use of a statewide database reporting all admissions in WA between 2000 and 2006 may have led

to an lower estimates of patients, admissions and hospital costs associated with single gene and chromosomal disorders compared to a record review of a tertiary hospital. Secondly, others have reported that using ICD codes to extract data from hospital morbidity records leads to an under-estimation of up to 25% of the true impact of genetic disease compared to using the same ICD10 codes in a manual review [11]

However, the direct review of hospital records is time and labor-intensive and studies are limited to one or two children's hospitals, whilst a population database approach reflects the entire population over time rather than specialized services or short-term trends. Thus, the two approaches are complementary and both add valuable information.

CONCLUSION

In conclusion, this paper provides the first description of the impact of single gene and chromosomal disorders on hospital services in Australia. We believe the Western Australian hospital morbidity database is a valuable resource for obtaining information about the impact of single gene and chromosomal disorders on hospital admissions, although it may provide a relatively conservative estimate, based on comparison with international studies. Data generated by this study will act as baseline data for future studies investigating the impact of genetic disease in WA and inform planning of hospital services, genetic testing, screening and counselling services; and genetic education for health professionals.

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Table 1. Studies examining the impact of genetic disease on pediatric hospitalizations.

Study	Methodology		Age range of patients surveyed	% admissions due to single gene and chromosomal	% admissions with a genetic component	Mean LOS of genetic versus all admissions (days)	Mean cost per admission for genetic versus all admissions USD
Scriver et al (1973)[11]	Hospital based record review[a]		≤ 18 years	7.2	29.7	-	-
Day & Holmes (1973)[6]	Hospital based record review[a]		unspecified	5.0/2.5[h]	53.0	-	-
Hall et al (1978)[4]	Hospital based record review[a]		unspecified	4.5	53.4	3.4 vs 3.0	450 vs 447
Carnivale et al (1985)[14]	Hospital based record review[a]		unspecified	4.3	37.8	-	-
FitzPatrick et al (1991)[7]	Hospital based record review[b]		unspecified	5.7	68.0	8.6 vs 4.2	
Pinto et al (1996)[15]	Hospital based record review[b]		infants	-	12.5		
Yoon et al (1997)[13]	Population, ICD code[c]	SC[d]	< 20 years	9.0	-	6.0 vs 4.4	8418 vs 4468
		Cal[d]		12.0		8.7 vs 5.7	25 532 vs 9009
Kumar et al (2001)[8]	Hospital based record review[e]		unspecified	-	18.6	-	-
Meguid et al (2003)[10]	Hospital based record review[e]		infants	11.1	-	-	-
McCandless et al (2004)[9]	Hospital based record review[a]		≤ 18 years	10.8	34.0	7.1 vs 6.6[f]	17 218 vs 6985[f]
Stanley et al (2009)[12]	Hospital based record review[a]		unspecified	9.8	48.9	-	-
This study	Population, ICD code[c, g]		≤ 19 years	2.8	-	6.7 vs 3.4	7613 vs 4144

[a] Sample taken from all admissions to a pediatric hospital or pediatric ward of a general hospital
[b] Sample taken from admissions to a pediatric intensive care unit or high risk ward
[c] Sample taken from a statewide population database
[d] SC – South Carolina, Cal - California
[e] Sample taken from admissions to a pediatric emergency department
[f] genetic conditions compared to non-genetic conditions, as “all admissions” LOS and cost not given
[g] 2006 data only
[h] inpatients/outpatients

Table 2. Hospital admissions and costs due to pediatric patients with genetic disorders, by type of disease.

Type of disorder	Patients	Admissions	Same day admissions[a]	Overnight admissions[a]	Mean no. admissions per patient	Mean LOS[b]	Total cost USD 2006-7	Cost per admission USD 2006-7
Disease of blood & blood forming organs	645	2707	1501 (0.55)	1206 (0.45)	4.2	6.2	12 107 744	4473
Disorders of the immune system	41	588	438 (0.74)	150 (0.26)	14.3	10.4	2 898 118	4929
Endocrine disorders	146	469	117 (0.25)	352 (0.75)	3.2	4.9	2 632 164	5612
Metabolic disorders	480	3105	1195 (0.38)	1910 (0.62)	6.5	8.0	28 096 934	9049
Neuromuscular disorders	364	1626	587 (0.36)	1039 (0.64)	4.5	6.0	11 170 262	6870
Diseases of the eye	163	665	311 (0.47)	354 (0.53)	4.1	6.5	4 286 864	6446
Diseases of the circulatory system	2	4	4 (1.00)	0 (0.00)	2.0	-	11 274	2819
Disorders of tooth development	115	200	161 (0.81)	39 (0.19)	1.7	1.6	577 316	2887
Diseases of the digestive system	4	14	0 (0.00)	14 (1.00)	3.5	6	276 011	19 715
Disease of the urinary system	51	96	20 (0.21)	76 (0.79)	1.9	3.3	673 941	7020
Diseases of the skeletal system	406	1652	961 (0.58)	691 (0.42)	4.0	7.6	7 540 242	4564
Diseases of the skin	32	119	50 (0.42)	69 (0.58)	3.7	5.4	542 756	4561
Chromosomal abnormalities, multiple systems	822	2952	1067 (0.36)	1885 (0.64)	3.6	7.6	18 251 432	6183
Total	3271	14 197	6 412 (0.45)	7785 (0.55)	-	-	89 065 059	6273
Mean	-	-	-	-	4.3	7.2		

[a] Proportion of total admissions due to same day versus overnight admissions are shown in brackets
[b] Length of stay

Table 3. Number of patients, admissions and length of stay of pediatric patients with genetic disorders in Western Australia, by age group (2006).

Age groups (years)	Patients[a]	Admissions[a]	Same day admissions[b]	Overnight Admissions[b]	Mean admissions per patient	Mean LOS[c]	Overall cost 2006[a] USD 2006-7	Mean cost per patient USD 2006-7	Mean cost per admission USD 2006-7
< 1	175 (0.20)	428 (0.19)	80 (0.19)	348 (0.81)	2.4	10.1	4 284 395 (0.26)	24 482	10 010
1 - 4	195 (0.23)	644 (0.28)	313 (0.49)	331 (0.51)	3.3	4.3	4 108 248 (0.25)	21 068	6379
5 - 9	238 (0.28)	482 (0.21)	273 (0.57)	209 (0.43)	2.0	5.2	2 865 527 (0.17)	12 040	5945
10 -14	133 (0.15)	352 (0.16)	151 (0.43)	201 (0.57)	2.6	7.6	2 107 166 (0.13)	15 843	5986
15 -19	117 (0.14)	335 (0.15)	111 (0.33)	224 (0.67)	2.9	6.6	3 182 548 (0.19)	27 201	9500
Total	858	2241	928 (0.41)	1313 (0.59)	-	-	16 547 883	-	-
Mean	-	-	-	-	2.6	6.7	-	19 287	7384

[a] The proportion of patients/admissions/costs in each age group is shown in brackets
[b] The proportion of admissions due to same day versus overnight admissions in each age group in shown in brackets
[c] LOS – length of stay of overnight patients only

Table 4. Number of patients, admissions and length of stay of all pediatric patients in Western Australia, by age group (2006)

Age groups (years)	Patients[a]	Admissions[a]	Same day admissions[b]	Overnight admissions[b]	Mean admissions per patient	Mean LOS[c]	Overall cost 2006[a] USD 2006-7	Mean cost per patient USD 2006-7	Mean cost per admission USD 2006-7
< 1	13 565 (0.23)	19 350 (0.25)	4890 (0.25)	14 460 (0.75)	1.4	6	118 848 700 (0.37)	8761	6142
1 - 4	8773 (0.15)	11 318 (0.14)	5791 (0.51)	5527 (0.49)	1.3	2	35 571 035 (0.11)	4054	3143
5 - 9	9908 (0.17)	12 516 (0.16)	6565 (0.52)	5951 (0.48)	1.3	2	40 300 218 (0.12)	4067	3220
10 -14	8646 (0.15)	11 368 (0.14)	5184 (0.46)	6184 (0.54)	1.3	3	41 889 389 (0.13)	4845	3685
15 -19	17 040 (0.30)	24 055 (0.31)	11 690 (0.49)	12 365 (0.51)	1.4	4	89 161 594 (0.27)	5232	3707
Total	57 932	78 607	34 120 (0.43)	44 487 (0.57)	-	-	325 770 936	-	-
Mean	-	-	-	-	1.4	3.4		5623	4144

[a] The proportion of patients/admissions in each age group is shown in brackets
[b] The proportion of admissions due to same day versus overnight admissions in each age group in shown in brackets
[c] LOS – length of stay of overnight patients only

Table 5. Proportion of hospital admissions and expenditure in Western Australia due to patients with genetic disorders (2006)

Age groups	% of patients with genetic disorders	% of admissions due to patients with genetics disorders	% of hospital costs due to patients with genetics disorders
< 1	1.3%	2.2%	3.6%
1 - 4	2.2%	5.7%	11.5%
5 - 9	2.4%	3.8%	7.1%
10 -14	1.5%	3.1%	5.0%
15 -19	0.7%	1.4%	3.6%
Mean	1.5%	2.8%	5.1%

Table 6. Hospital admissions and costs of the 10 most expensive genetic disorders described in pediatric patients with genetic disorders in Western Australia (2000 – 2006).

Genetic disorder	Total admissions and costs		Admissions & cost (USD 2006-7) by age group				
			< 1	1 - 4	5 - 9	10 - 14	15 - 19
E84 Cystic fibrosis	Adm	1678	227	364	177	282	628
	Cost	19 710 044	2 641 002	4 150 737	2 395 809	3 649 226	6 873 270
	Cost/Adm	11 746	11 634	11 403	13 536	12 941	10945
Q90 Down syndrome	Adm	1662	449	443	374	264	132
	Cost	10 517 070	5 509 028	1 944 815	1 380 075	1 085 187	597 965
	Cost/Adm	6328	12 270	4390	3690	4111	4530
Q87 Congenital malformations, multiple systems	Adm	599	150	157	132	61	99
	Cost	3 637 204	1 569 613	885 173	518 734	270 667	393 017
	Cost/Adm	6072	10 646	5638	3930	4437	3970
Q78 Osteochondroplasias (e.g. osteogenesis imperfecta)	Adm	1021	64	228	255	344	130
	Cost	3 561 122	431 423	739 367	891 957	1 071 689	426 686
	Cost/Adm	3488	6584	3243	3498	3115	3282
D68 Coagulation defects (e.g. Von Willebrands)	Adm	650	22	91	141	171	225
	Cost	3 018 165	152 775	514 805	625 961	612 681	1 111 943
	Cost/Adm	4643	6944	5657	4439	3583	4942
Q85 Phakomatoses (e.g. neurofibromatosis, tuberous sclerosis)	Adm	548	42	194	116	99	97
	Cost	2 369 206	224 463	685 226	400 231	529 427	529 859
	Cost/Adm	4323	5344	3532	3450	5348	5462
G71 Primary disorders of muscle	Adm	264	20	50	56	44	94
	Cost	2 193 691	364 389	396 132	413 058	293 922	726 190
	Cost/Adm	8309	18 219	7923	7376	6680	7725
G12 Spinal muscular atrophy	Adm	183	40	25	36	56	26
	Cost	2 165 107	541 763	482 644	435 228	568 721	136 751
	Cost/Adm	11 831	13 544	19 305	12 090	10 156	5260
Q69 Polydactyly	Adm	360	243	93	12	9	3
	Cost	2 000 731	1 325 527	484 491	107 731	56 700	26 282
	Cost/Adm	5558	5455	5210	8978	6300	8761
E88 Metabolic disorders[a]	Adm	267	41	102	53	47	24
	Cost	1 971 845	330 937	923 556	227 900	223 496	265 956
	Cost/Adm	7385	8072	9054	4300	4755	11 081
Total	Adm	7232	1298	1747	1352	1377	1458
	Cost	51 144 185	13 090 920	11 206 946	7 396 684	8 361 716	11 087 919
	Cost/Adm	7072	10 085	6415	5471	6072	7605

[a] Defects in the mitochondrial respiratory chain and antitrypsin deficiency

Supplementary Table 1. ICD-10-AM codes used to extract data from the Hospital Morbidity Database on single gene and chromosomal disorders

Clinical Categories	ICD-10-AM codes
Blood and blood forming organs	D511, D530, D550, D552, D558, D560-562, D564, D569, D570-573, D578, D580-D582, D588-589, D610, D640, D644, D66, D67, D680-682, D691, D694, D720, D750, D752
Immune function	D800, D810-813, D818-821, D823-824, D830, D831-832, D841
Endocrine	E030-031, E071, E078, E201, E208, E230, E250, E268, E291, E345
Metabolic	E700-703, E708, E711, E713, E720-725, E728-730, E740-744, E748, E750-752, E754-756, E760-763, E768-769, E771, E778-779, E791, E799, E800-E804, E806-807, E830-833, E835, E840-849, E850-851, E880, E888
Neuromuscular	F022, F842, G10, G110-119, G120-129[a], G230, G600-602, G608-609, G702, G710-713, G723, G901, Q030, Q044, Q850-851, Q8583
Eye and Ear	H185, H312, H355, Q111-112, Q120[a], Q130[a]
Circulatory system	I780, Q8582
Gastrointestinal tract and teeth	Q4312, Q4471, Q8581, Q8584, K000, K005
Skin and nails	L605, Q800, Q802-809, Q810, Q812, Q818-819, Q821, Q823-824
Skeletal	M145, M357, Q690-692, Q699, Q704, Q709, Q716, Q727, Q7481, Q7485, Q7505, Q7531, Q754, Q770-777, Q7781, Q7782, Q780-789, Q796
Renal	Q601, Q611, Q612-613, Q6150-6152
Multi-system syndromes	Q8702-8704, Q8706-8707, Q8712-8718, Q8721, Q8723, Q8724, Q8731-8732, Q874, Q8781-8782, Q8784-8785, Q8935, Q900-909, Q910-917, Q920-929, Q930-939, Q952-953, Q959, Q960-969, Q970-979, Q980-989, Q990-999

[a] Only a proportion of these conditions are due to a single gene defect. We included 10% of admissions for G122 (motor neuron disease); 30% for Q120 (congenital cataract); and 25% for Q130 (coloboma of iris)