European Journal of Endocrinology, 2026, 194, 102–113
https://doi.org/10.1093/ejendo/lvag010
Published: 19 January 2026
Original research

Endocrine and metabolic late effects in childhood cancer survivors in Germany: the VersKiK study

Pietro Trocchi [1]*, Enno Swart[1], Ekaterina Aleshchenko[1], Hiltrud Merzenich[2], Cecile Ronckers[2,3], Katja Baust[4], Gabriele Calaminus [4], Thorsten Langer [5], Peter Ihle[6], Jutta Küpper-Nybelen[6], Christian Lüpkes[7], Patrik Dröge[8], Thomas Ruhnke [8], Dirk Horenkamp-Sonntag[9], Ursula Marschall[10], Melanie Klein[11], Claudia Spix [2], Christian Apfelbacher [1] and Judith Gebauer[12]

[1]Institute of Social Medicine and Health Systems Research, Faculty of Medicine, Otto von Guericke University, 39120 Magdeburg, Germany
[2]German Childhood Cancer Registry, Division of Childhood Cancer Epidemiology, Institute of Medical Biostatistics, Epidemiology, and Informatics, University Medical Centre of Johannes Gutenberg University Mainz, 55101 Mainz, Germany
[3]Division of CAYA Cancer Survivorship Research, German Cancer Research Center, 69120 Heidelberg, Germany
[4]Department of Paediatric Haematology and Oncology, University Hospital Bonn, 53127 Bonn, Germany
[5]Department of Paediatric Haematology and Oncology, University Hospital of Schleswig-Holstein, Campus Lübeck, 23538 Lübeck, Germany
[6]PMV Research Group at the Department of Child and Adolescent Psychiatry, Psychotherapy, and Psychosomatics, University Hospital of Cologne and University of Cologne, Faculty of Medicine, 50931 Cologne, Germany
[7]OFFIS–Institute for Information Technology, 26121 Oldenburg, Germany
[8]AOK Research Institute (WIdO), 10178 Berlin, Germany
[9]Techniker Krankenkasse (TK), 22305 Hamburg, Germany
[10]BARMER, 42285 Wuppertal, Germany
[11]DAK-Gesundheit, 20097 Hamburg, Germany
[12]Department of Oncology and University Cancer Leipzig, University of Leipzig Medical Center, Liebigstraße 22, 04130 Leipzig, Germany
*Corresponding author: Institute of Social Medicine and Health Systems Research, Faculty of Medicine, Otto von Guericke University, Leipziger Str. 44, 39120 Magdeburg, Germany. Email: pietro.trocchi@med.ovgu.de

Abstract

Objective **Endocrine and metabolic diseases are known to be common late effects in childhood cancer survivors (CCS). We assessed the prevalence of these diseases in a large German CCS cohort, and a matched comparison population, using health claims data.**

Design **The cohort study was based on record linkage between the nationwide German Childhood Cancer Registry and claims data from 13 major German statutory health insurances.**

Methods **The monitored insurance period covered the years 2017-2021. We assessed the frequencies of endocrine and metabolic diseases among 11 863 five-year CCS, diagnosed 1991-2021, with continuous insurance coverage and a matched comparison group of 35 589 insured persons without a history of childhood cancer. We present prevalence and prevalence ratios (PR) with corresponding 95% confidence intervals (95% CI).**

Results **At least one endocrine or metabolic disease was recorded in 31.3% of survivors ($n = 3716$) and in 16.4% of the comparison group ($n = 5819$, PR = 1.9; 95% CI: 1.8-2.0). The frequency of diseases was higher among females than among males in both groups. The PR was 2.4 (95% CI: 2.3-2.5) for males and 1.6 (95% CI: 1.5-1.7) for females. The frequency of at least one disease increased with increasing attained age. The disease with the highest frequency among CCS was hypothyroidism (15.85%), and the highest PR was estimated for patients with primary thyroid cancer (43.5; 95% CI: 24.2-78.1).**

Conclusions **Our study highlights the increased vulnerability of CCS to endocrine and metabolic diseases compared to the general population and underscores the need for risk-adapted surveillance during the whole survivorship trajectory.**

Keywords childhood cancer, cancer survivorship, follow-up care, late effects, claims data, cancer registry

Received: October 2, 2025. **Revised:** December 17, 2025. **Accepted:** January 7, 2026

Significance statement

The aim of this study was to assess the frequency of endocrine and metabolic diseases among 5-year survivors of childhood cancer in Germany, comparing them with matched insurants from the general population.

We showed that approximately one-third of survivors (31.3%) suffered from at least one endocrine or metabolic disorder, with a frequency almost twice that of the general population. The most frequently occurring disease was hypothyroidism, while thyroid cancer showed the most pronounced increase in frequency compared to the comparison group.

Our results underscore the substantial clinical relevance of these sequelae for all childhood cancer survivors throughout the whole survivorship trajectory and may contribute to raising awareness and improved surveillance among healthcare providers for endocrine morbidity in these survivors.

Introduction

Due to advances in cancer treatment and care, over 80% of childhood cancer patients in Europe can expect 5-year survival.[1,2] Consequently, the number of childhood cancer survivors (CCS) has been increasing worldwide over the last decades.[3] Currently, there are over 500 000 CCS living in Europe. However, a large proportion of CCS has to deal with chronic health conditions as a consequence of their cancer and its treatment.[4] These disorders may persist after the end of cancer therapy or appear with a latency of several months to years after completion of cancer therapy (long-term or late effects, respectively). Furthermore, they contribute to CCS' elevated late mortality risk, mainly driven by second malignant neoplasms as well as nonmalignant conditions such as cardiovascular or pulmonary diseases.[5] The occurrence of long-term or late effects depends largely on cancer type and treatment exposure, but individual risk factors such as age at exposure, pre-existing conditions, and genetic predispositions, among others, modify the survivor's risk. As early diagnosis and treatment of late effects may result in better outcomes, several guidelines recommend risk-adapted screening as part of regular long-term follow-up.[6,7]

Endocrine diseases are among the most frequently reported late effects in CCS and affect up to 50% of survivors.[8] The most frequently reported endocrine conditions include primary hypothyroidism, hypothalamic-pituitary dysfunction, gonadal dysfunction, and diabetes mellitus.[9] Their occurrence is largely determined by exposure to radiotherapy (RT) and/or alkylating agent chemotherapy as the most relevant risk factors for endocrine sequelae.[10] Consequently, survivors of several childhood cancer types are particularly at risk and should be regularly screened to facilitate early detection of potential late effects.[11,12] Identification of vulnerable populations might help to improve completion of recommended screening among those most prone to develop endocrine late effects, considering limited access to surveillance examinations and specialized long-term follow-up clinics.[13]

The German Childhood Cancer Registry (GCCR) was established in 1980 and currently monitors all incident cases of malignant and selected nonmalignant diseases diagnosed in children and adolescents aged 0 to 17 years in Germany. The case registration process is based on voluntary reporting by all pediatric hematology-oncology units in Germany, with a high level of completeness of registration estimated for children aged 0-14 years at over 95%.[14]

In the present study, we quantitatively investigated the occurrence of endocrine and metabolic late effects for the first time in a large, unselected cohort of 5-year CCS registered in the GCCR and compared the frequency of these outcomes to that of the general population using claims data from German statutory health insurances (SHI). This analysis is part of the VersKiK study (*long-term care, care needs, and wellbeing of individuals after cancer in childhood or adolescence*).[15,16]

Materials and methods

Study design

Briefly, VersKiK is a retrospective registry-based cohort study that combined data of patients with childhood or adolescent cancer recorded in the GCCR with claims data of 13 major SHIs. The monitored SHI-insurance period covered the years 2017-2021. A randomly selected comparison group of insured individuals from the same SHIs was individually matched in a 1:3 ratio to former cancer patients according to year of birth, sex, region of residence, and insurance coverage.

Selection of subjects, available data

The VersKiK study included children and adolescents diagnosed with a neoplastic disease, as defined by the International Classification of Childhood Cancer (ICCC-3), between 1991 and 2021. According to GCCR-registration criteria, patients were under 15 years of age at first diagnosis (until 2008) or under 18 years of age (since 2009), respectively, and residents in Germany. Patients eligible for the study population had to be alive on January, 1, 2017 (start of the insurance period for which claims data are available for VersKiK). Overall, 49 624 patients met these criteria.

To identify these patients in the pool of the insured persons of the 13 participating SHI (study population), the encrypted GCCR identity data were stochastically linked with the encrypted identity data from the SHIs. Details on the linkage procedure are described elsewhere.[17] No relevant differences were found between the study population and the former patients who were not identified in SHI records with regard to attained age, sex, primary cancer diagnosis, and year of diagnosis.[17] For the 26 127 former childhood cancer patients identified in SHI records, both claims data (in- and outpatient diagnoses, utilization of outpatient medical services, hospitalizations, and medication prescriptions) and GCCR-based information on type of primary cancer, year of diagnosis, sex, year of birth, and current region of residence were analyzed. To study the frequency of endocrine and metabolic late

effects, we analyzed data of patients recorded in the GCCR who survived at least 5 years after the primary cancer diagnosis at the start of the observation period (January 2017). Furthermore, we selected the patients with continuous insurance coverage from January 2017 until the end of the monitored insurance period (December 2021) or date of death, whichever occurred first. This analysis group comprised 11 863 five-year survivors. Details of the inclusion and exclusion criteria and the derivation of the final data analysis file of the study are presented in Figure 1. From the pool of insured individuals without a documented history of childhood cancer who were alive on the day of the data extraction, we selected a 1:3 matched comparison population of 35 589 insured persons.

Data analysis

The primary study outcomes were the frequencies of the following endocrine and metabolic diseases recorded between January, 2017 and December, 2021 in SHI claims data according to the International Classification of Diseases (ICD-10): thyroid cancer, hypothyroidism, hyperthyroidism, thyroiditis, nontoxic goiter, hypoparathyroidism, hyperparathyroidism, hypopituitarism, disorders of adrenal gland, ovarian dysfunctions, testicular dysfunctions, disorders of puberty, diabetes mellitus type 1, diabetes mellitus type 2, and obesity (Table S1). The study outcomes were selected based on current knowledge in the medical literature of potential endocrine and metabolic late effects following childhood cancer. For example, hereditary conditions such as congenital adrenal hyperplasia, and acquired conditions with no documented association with cancer treatment, such as Cushing's disease, were excluded (Table S2). For this analysis, eligible outcomes were defined as diagnoses recorded at least once in 2 or more quarter-year periods during the insurance period.[18]

We calculated absolute and relative frequencies of outcomes for the 5-year CCS and for the persons of the matched comparison group. To assess patterns across different subpopulations, we stratified frequencies by sex and attained age (which is age at the beginning of the observation period). We also calculated the frequencies of endocrine and metabolic diseases for CCS according to primary cancer diagnosis, and follow-up period, which is the time interval from diagnosis to the start of the monitored insurance period. We descriptively compared the frequencies of the 2 groups by estimating the ratios of the relative frequencies (RF) (prevalence ratio (PR) $= RF_{patient}/RF_{comparison}$), and their 95% confidence intervals (95% CI), by using binomial conditional log-linear regression models. Confidence intervals were estimated according to the Wald method.

Several approaches to assess the cumulative burden of chronic health impairments in CCS have been proposed in the literature, often based on the mean cumulative count (MCC) method, which accounts for multiple events during follow-up.[4,19] Investigators from the St. Jude Lifetime Cohort Study derived their MCC analyses using Common Terminology Criteria for Adverse Events severity grading, which requires detailed clinical information that was unfortunately not available for our cohort. We therefore applied the approach proposed by the investigators of the Dutch Childhood Cancer Survivor Study, who calculated cumulative burden using the MCC method interpreted as the average number of outcomes per CCS or control up to a specific time point (end of the monitored insurance period: December, 31, 2021).[19]

Results

The CCS cohort included 11 863 five-year survivors diagnosed with primary childhood cancer during 1991-2011 and surviving until 2017 (earliest available insurance data). These persons were more likely to be male than female (55.9% and 44.1%,

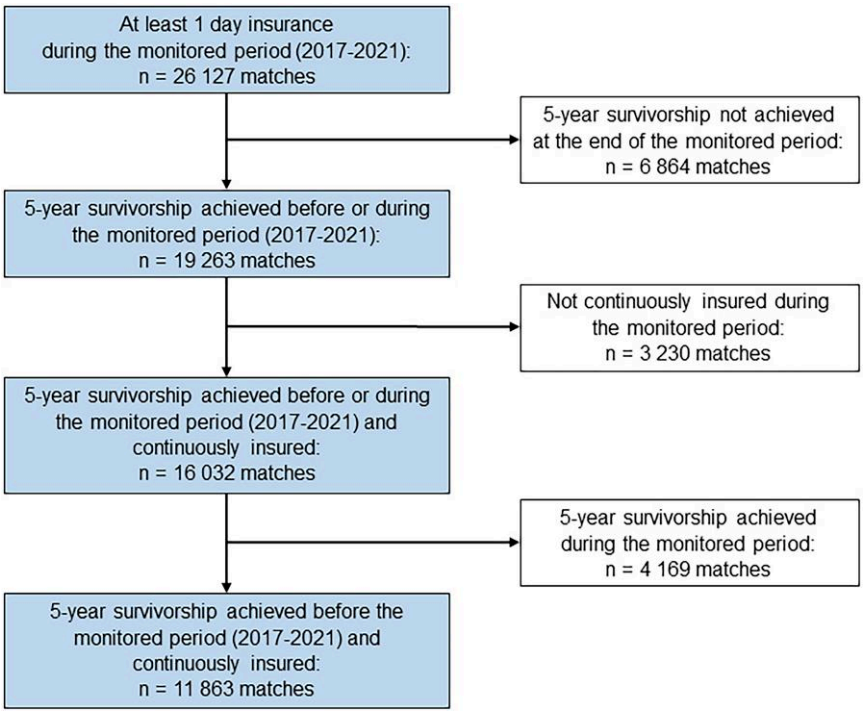

Figure 1 Flowchart outlining the identification of the study cohort of 5-year childhood cancer survivors.

respectively) and the largest subgroup was leukemia patients (29.5%). On January, 1, 2017, the mean age was 21.1 years (range: 5-40 years) and the mean time since cancer diagnosis was 14.6 years. At the end of the insurance period (December, 31, 2021), 98.5% of the persons were alive (Table 1).

Table 1 Basic characteristics of the study cohort of 5-year childhood cancer survivors (cancer diagnosis 1991-2011).

Characteristic	
Sex: *N* (%)	
Female	5236 (44.1)
Male	6627 (55.9)
Primary cancer diagnosis (ICCC3 Class): *N* (%)	
Acute lymphoid leukemia (I(a))	3459 (29.5)
Acute myeloid leukemia (I(b))	478 (4.0)
Hodgkin lymphoma (II(a))	669 (5.6)
Non-Hodgkin lymphoma (II(b-c))	825 (7.0)
Tumor of central nervous system (III(a-g))	2413 (20.3)
Neuroblastoma (IV(a-b))	789 (6.7)
Renal tumor (VI(a-b))	758 (6.4)
Bone tumor (VIII(a-e))	466 (4.0)
Soft tissue sarcoma (IX(a-e))	618 (5.2)
Intracranial germ cell tumor ((X(a)))	120 (1.0)
Other diagnoses[a]	1268 (10.7)
Age at January, 1, 2017[b] (years): mean (range)	21.1 (5-40)
Time since cancer diagnosis until January, 1, 2017 (years): mean (range)	14.6 (5-25)
Vital status on December, 31, 2021: *N* (%)	
Alive	11 681 (98.5)
Deceased in 2017-2021	182 (1.5)
Total: *N* (%)	11 863 (100)

[a]Including: unspecified lymphomas, unspecified malignant renal tumors, tumors of liver, malignant extracranial, gonadal and extragonadal germ cell tumors, malignant epithelial neoplasms and malignant melanomas, and other and unspecified malignant neoplasms.
[b]Start date of the claims-based insurance period for monitoring health and health care utilization outcomes (January, 1, 2017-December, 31, 2021).

Table 2 presents the frequency of any endocrine and metabolic disease among CCS and persons of the comparison group without a history of childhood cancer. At least one disease was recorded in 31.3% ($n = 3716$) of CCS and in 16.4% ($n = 5819$) of the comparison group (PR = 1.9; 95% CI: 1.8-2.0). The frequency of males with at least one disease was 26.9% among CCS and 11.2% for the comparison group (PR = 2.4; 95% CI: 2.3-2.5). For females, the frequency was 36.9% and 22.9%, respectively (PR = 1.6; 95% CI: 1.5-1.7). The frequency of diseases increased steadily in both groups with increasing attained age. However, the corresponding PR decreased from 2.3 for persons aged 5 < 10 years to 1.6 for those aged >30 years in January 2017. Among CCS, the frequency of diseases increased with increasing time since cancer diagnosis (0.50% per year).

At least 2 different endocrine and metabolic diseases were diagnosed in 13.5% of CCS and more than 2 different diseases in 5.6% of them (4.3% and 1.2% for the comparison group, respectively). Figure 2 shows the frequency of the cumulative number of outcomes in both groups.

The mean number of outcomes was 2.4-fold higher among survivors than among the comparison group: 0.53 (95% CI: 0.52-0.55) and 0.22 (95% CI: 0.22-0.23), respectively. In both groups, this number was higher for females than for males: 0.65 (95% CI: 0.62-0.68) and 0.44 (95% CI: 0.42-0.46), respectively, for survivors, and 0.33 (95% CI: 0.32-0.34) and 0.14 (95% CI: 0.13-0.15) for the comparison group. We also estimated an average increase in the number of outcomes for each year of age of 0.016 for survivors and 0.011 for the comparison group.

The frequency of specific endocrine and metabolic diseases in the study population is presented in Table 3. Among CCS, the frequency was higher in females than in males, with the exception of hyperparathyroidism. Among persons of the comparison group, the frequency of thyroid diseases for females was more than 3 times as high as for males, thereby resulting in PRs for these disorders being more than double among males compared to females. Except for hypopituitarism, disorders of puberty, and DM type 1, the frequency of specific diseases among CCS increased with attained age. The highest frequency was observed for hypothyroidism: 15.85% compared to 5.99% among the matched comparisons (PR = 2.6; 95% CI: 2.5-2.8). Hypoparathyroidism was

Table 2 Frequency of any endocrine and metabolic disorder[a] in the study cohort of childhood cancer survivors (year of diagnosis: 1991-2011) and comparison group.

Characteristic	Survivors	Comp. group	PR (95% CI)
Overall, *n*; %	3716/11 863; 31.3	5819/35 589; 16.4	1.9 (1.8-2.0)
Age at January, 1, 2017, *n*; %			
5 < 10 years	174/785; 21.9	227/2385; 9.5	2.3 (1.9-2.8)
10 < 20 years	1218/4489; 27.1	1729/13 623; 12.7	2.1 (2.0-2.3)
20 < 30 years	1744/5118; 34.1	2747/15 164; 18.1	1.9 (1.8-2.0)
≥30 years	580/1461; 39.7	1116/4417; 25.3	1.6 (1.4-1.7)
Sex, *n*; %			
Male	1785/6627; 26.9	2222/19 869; 11.2	2.4 (2.3-2.5)
Female	1931/5236; 36.9	3597/15 720; 22.9	1.6 (1.5-1.7)
Follow-up period[b], mean frequency increase per year (SE)	0.50 (0.05)	—	—

Abbreviations: CI, confidence interval; PR, prevalence ratio; SE, standard error.
[a]At least one recorded diagnosis repeated in at least 2 different quarters during the observation period (2017-2021).
[b]Time since cancer diagnosis until January, 1, 2017.

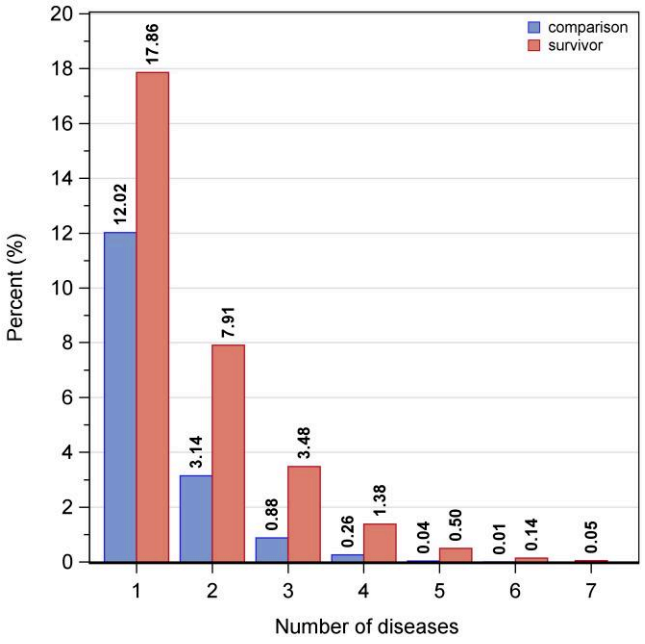

Figure 2 Frequency of the number of endocrine and metabolic diseases in the study cohort of 5-year childhood cancer survivors and the comparison group.

present in our study population with a low frequency, both in CCS (0.33%) and the comparison group (0.02%). The frequency of thyroid cancer as a subsequent neoplasm was 1.47% among CCS and 0.03% as a primary diagnosis in the comparison group (PR = 43.5; 95% CI: 24.2-78.1). Also, a high PR was observed for hypopituitarism (PR = 35.0; 95% CI: 26.8-45.7).

Table 4 presents the frequency of endocrine disorders among CCS according to childhood cancer type and time since first cancer diagnosis. High frequencies were found among CCS with intracranial germ-cell tumors, Hodgkin lymphoma, or tumors of the central nervous system. Among CCS with a diagnosis of an intracranial germ-cell tumors, we observed high prevalence for hypothyroidism (36.7%), hypopituitarism (55.0%), disorders of the adrenal gland (10.0%), and ovarian and testicular dysfunctions (9.1% and 11.8%, respectively). The frequency of hypothyroidism and nontoxic goiter among CCS with Hodgkin lymphoma was 34.8% and 20.3%, respectively. Among CCS with tumors of the central nervous system, the frequencies of hypothyroidism (23.4%), hypopituitarism (17.5%), disorders of the adrenal gland (2.4%), testicular dysfunctions (5.5%), and disorders of puberty (2.4%) were considerably increased when compared with the corresponding frequencies in the overall CCS cohort. The frequency of nontoxic goiter and hypothyroidism increased with time since cancer diagnosis (0.41 and 0.30 per year, respectively).

Discussion

In the present study, we report a consistently high prevalence of endocrine and metabolic disorders in 11 863 CCS, with about out of 3 survivors (31.3%) affected by at least one endocrine or metabolic disorder. This is almost twice as many as documented in the control group, indicating a substantially higher vulnerability as late effects of the disease and/or its therapy. Also, the risk for these conditions increased with increasing attained age, highlighting the need for continued open-ended surveillance during the survivorship trajectory.

Our results are in line with previously published studies mainly performed in the slightly older North American CCS cohort (mean age: 32 years) revealing a self-reported prevalence of 1 endocrinopathy in 44%, 2 in 16.7%, and 3 or more in 6.6% of the survivors (in our cohort: mean age 21.1 years, 31.3%, 13.5%, and 5.6%, respectively).[20]

The most frequent endocrine disorders reported in our cohort were thyroid disorders, especially hypothyroidism, which affected over 20% of CCS by the age of 30 years or older, and nontoxic goiter, which affected more than 11% of them. Although thyroid disorders account for the majority of endocrine conditions in the general population as well, there was still a more than doubled risk after being diagnosed with childhood cancer versus the comparison group (hypothyroidism: PR = 2.6, hyperthyroidism: PR = 2.2, nontoxic goiter: PR = 2.3) and was most pronounced in survivors of Hodgkin lymphoma (frequency of hypothyroidism: 34.83%, frequency of nontoxic goiter: 20.33%).

Intriguingly, we observed a higher PR for thyroid and parathyroid disorders among males than females. While several previous studies have reported gender-related differences in the occurrence of endocrine late effects, these differences were often attributed to varying rates of gonadal insufficiencies.[21] Some studies also showed a higher risk for thyroid disorders in female CCS.[22] However, the methodologies of earlier studies were heterogeneous, frequently relying on self-reported data or single-point clinical assessments, potentially limiting their comparability. Furthermore, findings from non-European populations—particularly those from North America and Canada—are only partially generalizable to the European context, given the differing baseline prevalences of endocrine disorders in the general population.

Hyperparathyroidism constitutes a rare sequela of cervical RT exposure, typically manifesting after RT exposure with a long latency.[13] In our cohort, however, we already observed a high prevalence of hyperparathyroidism in younger survivors with possible implications for long-term surveillance. Interestingly, 0.33% of CCS were affected by hypoparathyroidism with a PR of over 14 compared to the general population, which has previously not been described in CCS. Consequently, we performed a sub-cohort analysis revealing two-thirds of these patients were also affected by thyroid cancer, thus rendering hypoparathyroidism, a typical complication of thyroid cancer surgery, an indirect consequence of childhood cancer treatment as a risk to developing thyroid cancer. Thyroid cancer itself showed the most pronounced risk elevation with a PR of 43.5 when compared to non-childhood cancer controls. Considering the long-term consequences of this disease and thyroidectomy, in some cases with concomitant hypoparathyroidism, performed as the standard treatment, awareness of this late effect typically occurring after RT exposure of the thyroid gland is essential. Optimal surveillance strategies for this late effect are still under debate, ranging from counseling to neck palpation or periodic thyroid ultrasound, recognizing both benefits and harms (of overdiagnosis and overtreatment) for this subsequent cancer generally associated with a good long-term prognosis.[11,23]

The second most pronounced risk in 5-year survivors compared to the general population was observed for hypopituitarism

Table 3 Frequency of specific endocrine and metabolic disorders[a] in the study cohort of childhood cancer survivors (year of diagnosis: 1991-2011) and the comparison group.

Disorder ICD-10 Code	Characteristic	Survivors ($n = 11\,863$) %	Comp. group ($n = 35\,589$) %	PR (95% CI)
Thyroid cancer C73	Overall	1.47	0.03	43.5 (24.2-78.1)
	Age at January, 1, 2017			
	5 < 10 years	0.38	0	—
	10 < 20 years	1.00	0.01	68.3 (16.6-281.4)
	20 < 30 years	1.84	0.04	46.4 (20.3-105.9)
	≥30 years	2.19	0.09	24.2 (8.6-68.3)
	Sex			
	Male	1.15	0.02	76.0 (24.0-240.7)
	Female	1.87	0.06	32.7 (16.6-64.7)
Hypothyroidism E03.2/4/8/9, E89.0	Overall	15.85	5.99	2.6 (2.5-2.8)
	Age at January, 1, 2017			
	5 < 10 years	8.18	0.67	12.2 (7.1-20.9)
	10 < 20 years	12.72	3.99	3.2 (2.9-3.6)
	20 < 30 years	18.33	7.39	2.5 (2.3-2.7)
	≥30 years	20.94	10.26	2.0 (1.8-2.3)
	Sex			
	Male	13.14	2.85	4.6 (4.2-5.1)
	Female	19.27	9.96	1.9 (1.8-2.1)
Hyperthyroidism E05	Overall	1.58	0.73	2.2 (1.8-2.6)
	Age at January, 1, 2017			
	5 < 10 years	0.13	0.04	3.0 (0.2-47.9)
	10 < 20 years	1.16	0.35	3.3 (2.2-4.9)
	20 < 30 years	1.91	0.92	2.1 (81.6-2.7)
	≥30 years	2.53	1.61	1.6 (1.1-2.3)
	Sex			
	Male	1.10	0.27	4.1 (2.9-5.8)
	Female	2.20	1.30	1.7 (1.3-2.1)
Thyroiditis E06	Overall	2.98	2.18	1.4 (1.2-1.5)
	Age at January, 1, 2017			
	5 < 10 years	0.88	0.34	2.6 (1.0-7.2)
	10 < 20 years	2.16	1.24	1.7 (1.4-2.2)
	20 < 30 years	3.46	2.69	1.3 (1.1-1.5)
	≥30 years	4.93	4.32	1.1 (0.9-1.5)
	Sex			
	Male	1.66	0.67	2.5 (1.9-3.2)
	Female	4.64	4.09	1.1 (1.0-1.3)
Nontoxic goiter, other iodine-deficiency-related thyroid disorders E04, E01.8	Overall	6.10	2.64	2.3 (2.1-2.5)
	Age at January, 1, 2017			
	5 < 10 years	1.01	0.29	3.4 (1.2-9.4)
	10 < 20 years	4.14	1.45	2.9 (2.4-3.5)
	20 < 30 years	7.11	3.11	2.3 (2.0-2.6)
	≥30 years	11.36	6.00	1.9 (1.6-2.3)
	Sex			
	Male	4.68	1.23	3.8 (3.2-4.5)
	Female	7.91	4.43	1.8 (1.6-2.0)

(*continued*)

Table 3 Continued

Disorder ICD-10 Code	Characteristic	Survivors ($n = 11\,863$) %	Comp. group ($n = 35\,589$) %	PR (95% CI)
Hypoparathyroidism E20.0/8/9, E89.2	Overall	0.33	0.02	14.6 (6.8-31.3)
	Age at January, 1, 2017			
	5 < 10 years	0	0	—
	10 < 20 years	0.25	0.01	33.4 (4.3-258.5)
	20 < 30 years	0.41	0.04	10.4 (4.2-25.7)
	≥30 years	0.48	0.02	21.2 (2.6-171.9)
	Sex			
	Male	0.23	0.01	22.5 (5.1-98.3)
	Female	0.46	0.04	12.0 (4.9-29.4)
Hyperparathyroidism E21.0/1/2/3	Overall	0.46	0.06	7.2 (4.4-11.7)
	Age at January, 1, 2017			
	5 < 10 years	0.13	0	—
	10 < 20 years	0.29	0.04	7.9 (2.8-22.1)
	20 < 30 years	0.53	0.08	6.7 (3.4-13.1)
	≥30 years	0.96	0.14	7.1 (2.7-18.3)
	Sex			
	Male	0.47	0.06	8.4 (4.2-16.8)
	Female	0.46	0.08	6.0 (3.0-12.0)
Hypopituitarism E23.0/1/2/3, E89.3	Overall	5.71	0.16	35.0 (26.8-45.7)
	Age at January, 1, 2017			
	5 < 10 years	4.28	0.13	34.0 (10.5-110.4)
	10 < 20 years	6.01	0.21	28.3 (19.3-41.4)
	20 < 30 years	5.98	0.13	47.7 (30.1-75.8)
	≥30 years	4.59	0.16	28.9 (13.3-62.9)
	Sex			
	Male	5.61	0.17	34.9 (24.3-50.0)
	Female	5.83	0.16	35.2 (23.6-52.5)
Disorder of adrenal gland E27.1/4, E89.6	Overall	0.81	0.04	22.2 (12.4-39.5)
	Age at January, 1, 2017			
	5 < 10 years	0.13	0	—
	10 < 20 years	0.76	0.05	14.7 (6.5-33.2)
	20 < 30 years	0.92	0.03	34.8 (12.6-96.6)
	≥30 years	0.96	0.05	22.2 (4.8-93.0)
	Sex			
	Male	0.71	0.04	20.1 (9.1-44.5)
	Female	0.94	0.04	24.5 (10.5-57.2)
Ovarian dysfunction, postprocedural ovarian failure E28.3, E89.4	Overall	3.48	0.17	21.0 (14.0-31.7)
	Age at January, 1, 2017			
	5 < 10 years	1.33	0	—
	10 < 20 years	3.62	0.10	35.1 (15.3-80.7)
	20 < 30 years	3.53	0.21	16.9 (9.6-29.8)
	≥30 years	4.06	0.29	14.0 (5.8-33.7)
Testicular dysfunction, postprocedural testicular hypofunction E29.1, E89.5	Overall	3.02	0.20	15.0 (16.7-21.0)
	Age at January, 1, 2017			
	5 < 10 years	0.48	0.16	3.0 (0.4-21.3)
	10 < 20 years	2.66	0.15	17.3 (9.4-31.9)
	20 < 30 years	3.51	0.25	14.1 (8.8-22.6)

(*continued*)

Table 3 Continued

Disorder ICD-10 Code	Characteristic	Survivors ($n = 11\,863$) %	Comp. group ($n = 35\,589$) %	PR (95% CI)
	≥30 years	3.76	0.21	17.7 (6.9-45.5)
Disorders of puberty	Overall	1.09	0.08	14.3 (9.5-21.7)
E22.8, E30	Age at January, 1, 2017			
	5 < 10 years	2.01	0.25	8.0 (3.1-20.4)
	10 < 20 years	2.16	0.15	14.7 (9.1-23.8)
	20 < 30 years	0.27	0.01	41.5 (5.5-315.4)
	≥30 years	0.14	0	—
	Sex			
	Male	0.92	0.07	14.1 (7.7-25.6)
	Female	1.30	0.09	14.6 (8.2-25.9)
Diabetes mellitus, type 1	Overall	0.89	0.60	1.5 (1.2-1.9)
E10	Age at January, 1, 2017			
	5 < 10 years	0.38	0.46	0.8 (0.2-2.9)
	10 < 20 years	0.56	0.61	0.9 (0.6-1.4)
	20 < 30 years	1.27	0.56	2.3 (1.6-3.1)
	≥30 years	0.89	0.79	1.1 (0.6-2.1)
	Sex			
	Male	0.89	0.62	1.4 (1.0-1.9)
	Female	0.90	0.57	1.6 (1.1-2.2)
Diabetes mellitus, type 2	Overall	2.12	0.79	2.7 (2.3-3.2)
E11	Age at January, 1, 2017			
	5 < 10 years	0.38	0.04	9.0 (0.9-84.4)
	10 < 20 years	0.91	0.31	3.0 (1.9-4.5)
	20 < 30 years	2.89	0.90	3.2 (2.5-4.0)
	≥30 years	4.04	2.26	1.8 (1.3-2.4)
	Sex			
	Male	1.77	0.68	2.6 (2.0-3.3)
	Female	2.56	0.92	2.8 (2.2-3.5)
Obesity	Overall	10.71	8.69	1.2 (1.2-1.3)
E66	Age at January, 1, 2017			
	5 < 10 years	8.93	7.88	1.1 (0.9-1.5)
	10 < 20 years	9.56	7.46	1.3 (1.2-1.4)
	20 < 30 years	11.27	9.01	1.3 (1.1-1.4)
	≥30 years	13.21	11.82	1.1 (1.0-1.3)
	Sex			
	Male	8.93	7.02	1.3 (1.2-1.4)
	Female	12.95	10.80	1.2 (1.1-1.3)

Abbreviations: CI, confidence interval; Comp., comparison; PR, prevalence ratio.
[a]At least one recorded diagnosis repeated in at least 2 different quarters during the observation period (2017-2021).

(PR = 35), typically occurring in brain tumor survivors and those exposed to cranial RT, consistent with results from former studies.[24] However, as most hypothalamic-pituitary insufficiencies present with nonspecific symptoms, they are likely to be overlooked if no appropriate diagnostics are initiated. In this context, a possible mix-up in diagnosis between primary and central adrenal insufficiency at the documentation level cannot be excluded, as primary adrenal insufficiency, although reported to occur more frequently in CCS in our analysis, is currently not known as a common late effect of cancer treatment.

Furthermore, when compared with the general population, a relevant share of CCS was affected by hypogonadism (ovarian and testicular dysfunction: PR = 21.0 and PR = 15.0, respectively) and puberty disorders, present in survivors of both sexes and already at a younger age, highlighting the need for screening and awareness of these sequelae as adequate treatment contributes,

Table 4 Frequency of endocrine and metabolic disorders[a] during 2017-2021 in the VersKiK cohort of childhood cancer survivors (year of diagnosis: 1991-2011, continuously insured, $n = 11\,863$) according to cancer diagnosis and time since cancer diagnosis.

	Disorder: %							
	Hypothyroidism	**Nontoxic goiter**	**Hyperparathyroidism**	**Hypopituitarism**	**Disorder of adrenal gland**	**Ovarian dysfunction**	**Testicular dysfunction**	**Disorder of puberty**
Overall	15.85	6.10	0.46	5.71	0.81	3.48	3.02	1.09
(age at January, 1, 2017 (years), mean)	(22.9)	(24.7)	(24.9)	(21.0)	(22.4)	(22.1)	(22.7)	(14.9)
Cancer diagnosis								
Lymphoid leukemia	11.25	5.55	0.32	1.53	0.20	2.73	2.91	0.52
Acute myeloid leukemia	16.53	5.65	0.42	4.60	0	8.16	3.00	1.46
Hodgkin lymphoma	34.83	20.33	0.45	0.45	0.15	3.10	1.95	0.30
Non-Hodgkin lymphoma	8.48	3.15	0.85	0.73	0	3.51	0.84	0.36
Tumor of the central nervous system	23.41	6.01	0.41	17.53	2.40	3.14	5.48	2.45
Neuroblastoma	12.93	5.58	0.76	2.03	0.63	1.42	1.60	0.89
Renal tumor	7.12	2.90	0.66	0.53	0.40	1.46	1.16	1.06
Bone tumor	12.88	6.87	0.64	1.93	0.21	4.48	1.23	0
Soft tissue sarcoma	12.78	5.83	0.65	6.31	0.32	4.63	2.37	1.78
Intracranial germ cell tumor	36.67	5.00	0.83	55.00	10.00	9.09	11.84	.83
Other	16.17	4.57	0.24	2.84	0.55	5.39	2.90	1.03
Follow-up period[b], mean frequency increase per year (standard error)	0.30 (0.06)	0.41 (0.04)	0.03 (0.01)	−0.10 (0.05)	0.00 (0.01)	0.00 (0.05)	0.03 (0.04)	−0.12 (0.02)

[a]At least one recorded diagnosis repeated in at least 2 different quarters during the observation period.
[b]Time since cancer diagnosis until January, 1, 2017.

among others, to improved bone health. Reduced bone mineral density represents a common late effect of cancer treatment that may deteriorate further if endocrine dysfunctions such as hypogonadism or growth hormone deficiency remain untreated.[25] In our cohort, the prevalence of bone diseases was very low due to the relatively young age of the individuals.

Metabolic disorders are common and generally rising in CCS as well as in the general population. They contribute to an increased cardiovascular risk and are an important target of preventive measures and interventions in this at-risk population.[5] In our cohort, we report a PR = 2.7 (95% CI: 2.3-3.2) for diabetes mellitus (DM) type 2 with a prevalence of 4% in CCS at the age of 30 years or older. These results are in good agreement with those of Bolier et al., who recently reported a 3-fold increased risk of DM in an older CCS cohort (median age 34.7 years), emphasizing the need for early intervention to support metabolic health.[26]

Endocrine and metabolic disorders are among the most common late effects of cancer and are generally amenable to treatment. However, many of these conditions present with nonspecific or even a lack of symptoms at the beginning, often resulting in delayed diagnosis and treatment, which contributes to a reduced quality of life and adverse long-term outcomes in CCS.[8,27] Furthermore, these conditions might elevate the risk for subsequent conditions that seriously affect survivors' long-term prognosis, such as cardiovascular disorders.[5] Dixon et al. stated that the promotion of risk reduction for CCS across their lifespan includes, amongst others, early detection of anticipated late effects of cancer treatment and prevention and control of modifiable cardiovascular risk factors such as metabolic late effects (especially diabetes mellitus and obesity). Consequently, numerous guidelines emphasize periodic screening for endocrine and metabolic late effects in at-risk CCS; however, adherence to these guideline recommendations is low, contributing to a continued high number of affected individuals receiving suboptimal treatment.[27] Identifying vulnerable populations to be counseled about long-term follow-up recommendations and to be addressed in clinical practice might improve endocrine and metabolic outcomes in CCS and thus contribute to better long-term health.

The increased vulnerability to metabolic diseases in younger CCS reported in this study suggests that these survivors are at risk of premature aging, resulting in an earlier occurrence of age-related diseases than in the general population in the same age group. Considering the young mean age of 21 years in our study cohort, this translates to a high burden of metabolic late effects and emphasizes the need for tailored risk-based screening for these disorders already beginning in adolescent and young adult CCS.

Our study provides important new insights, as it confirms findings from smaller or more selected cohorts in a large, unselected population of CCS with diverse cancer types and very long follow-up. This underscores the need for continuous monitoring of endocrine function after childhood cancer, a practice that is still not implemented consistently.

Strengths and limitations

Due to the involvement of a large number of SHIs, this study is based on a nationwide representative population of childhood and adolescent cancer survivors in Germany, allowing for high generalizability of the results to other populations with similar characteristics. The relevance of the findings is high as our study included an unselected cohort of survivors of all childhood cancer entities (as defined by the IARC) combined with data from the general non-childhood cancer population based on SHI record data representing medically confirmed diagnoses rather than self-reported outcomes. The large number allows us to focus on multiple rather than only one or a few endocrine or metabolic late effects as well as study rare endocrine diseases. Notably, there is no information available on the utilization of Long-Term Follow-Up programs in our cohort. The true incidence of asymptomatic endocrine or metabolic late effects may thus be even higher than reported in our cohort. However, similar underdiagnoses or delayed diagnoses would likely apply to the comparison group too.

Our study has some limitations. First, our study included only CCS who had survived until at least 2017. This is associated with a survivor bias: CCS who died before 2017 were not eligible for an assessment of their late sequelae. Analyzing just a limited fixed follow-up period also prevents disentangling the trends by attained age and time since diagnosis. Second, the VersKiK project was based on claims data from 13 SHIs. Private insurance companies with a relatively larger proportion of high-income persons, but covering only about 8% of the general population, did not contribute data to the project. Third, the SHI insurance period covered the years between 2017 and 2021, as defined according to the latest available SHI data, allowed for the assessment of the burden of late effects by prevalence, but did not allow an estimation of incidence. Fourth, our results may, to some extent, have been influenced by better medical surveillance of survivors compared to the control population. However, over time, the intensity of medical surveillance tends to decrease in survivors and, as a result, the difference compared to the control group would also decrease. Since our study includes 5-year survivors, the period of insurance coverage during which surveillance bias may have had the strongest influence was excluded. Finally, due to the lack of information on the therapies of survivors, it was not possible to analyze the frequency of endocrine and metabolic diseases according to factors related to types and doses of treatments.

In conclusion, the results of the present study highlight the increased vulnerability of CCS to early-onset endocrine and metabolic diseases compared to the general population due to the long-term effects of cancer and/or its treatment. Our findings underscore the clinical relevance of increased awareness among healthcare providers regarding endocrine morbidity in CCS, emphasizing the need for gender-specific, risk-adapted long-term follow-up strategies and the importance of early screening of these survivors from a young age.

Author's contributions

Pietro Trocchi (Formal analysis [lead], Methodology [equal], Writing—original draft [lead]), Enno Swart (Conceptualization [lead], Data curation [lead], Funding acquisition [lead], Methodology [equal], Project administration [lead], Supervision [lead], Writing—original draft [equal]), Ekaterina Aleshchenko (Conceptualization [equal], Methodology [equal], Writing—original draft [equal]), Hiltrud Merzenich (Methodology [equal], Writing—original draft [equal]), Cecile Ronckers (Methodology [equal],

Writing—original draft [equal]), Katja Baust (Methodology [equal], Writing—review & editing [equal]), Gabriele Calaminus (Methodology [equal], Writing—review & editing [equal]), Thorsten Langer (Methodology [equal], Writing—review & editing [equal]), Peter Ihle (Data curation [equal], Methodology [equal], Writing—review & editing [supporting]), Jutta Küpper-Nybelen (Data curation [equal], Methodology [equal]), Christian Lüpkes (Software [lead]), Patrik Dröge (Data curation [equal]), Thomas Ruhnke (Data curation [equal]), Dirk Horenkamp-Sonntag (Data curation [equal]), Ursula Marschall (Data curation [equal]), Melanie Klein (Data curation [equal]), Claudia Spix (Methodology [equal], Writing—original draft [equal]), Christian Apfelbacher (Conceptualization [lead], Methodology [equal], Writing—original draft [equal]), and Judith Gebauer (Investigation [equal], Methodology [equal], Writing—original draft [lead])

Supplementary material

Supplementary material is available at *European Journal of Endocrinology* online.

Conflict of interest

The authors declare no competing interests.

Funding

The VersKiK study was funded by the Innovation Fund of the Federal Joint Committee in Germany [Gemeinsame Bundesausschuss (G-BA)] (grant reference no. 01VSF19013). The funder has no role in the design of the study and is not involved in its execution, data analysis, and dissemination of results.

Data availability

The data underlying this article cannot be shared publicly due to German data protection laws ("Bundesdatenschutzgesetz," BDSG). Access to data of statutory health insurance funds for research purposes is possible only under the conditions defined in German Social Law (SGB V § 287). The data can be shared on reasonable request as a formal proposal specifying the recipient and purpose of the data transfer to the appropriate data protection agency.

Ethics statement

The study complied with the Declaration of Helsinki and was approved by the Ethics Committee of the Otto von Guericke University on 2.07.2021 (103/21), by the Ethics Committee of the Johannes Gutenberg University Mainz on 16.06.2021 (2021-16035), by the Ethics Committee of the University Luebeck on 10.11.2021 (21-451), and by the Ethics Committee of the University Bonn on 28.02.2022 (05/22). According to the Federal Office of Social Security on 28.03.2022 (117-8261-2557/2021), individual written consent of the survivors to participate is not needed as only anonymized data are transferred and processed by the data-providing institutions.

References

1. Botta L, Gatta G, Capocaccia R, et al. Long-term survival and cure fraction estimates for childhood cancer in Europe (EUROCARE-6): results from a population-based study. *Lancet Oncol*. 2022;23(12):1525-1536. https://doi.org/10.1016/S1470-2045(22)00637-4
2. Ehrhardt MJ, Krull KR, Bhakta N, et al. Improving quality and quantity of life for childhood cancer survivors globally in the twenty-first century. *Nat Rev Clin Oncol*. 2023;20(10):678-696. https://doi.org/10.1038/s41571-023-00802-w
3. Shapiro CL. Cancer survivorship. *N Engl J Med*. 2018;379(25):2438-2450. https://doi.org/10.1056/NEJMra1712502
4. Bhakta N, Liu Q, Ness KK, et al. The cumulative burden of surviving childhood cancer: an initial report from the St Jude Lifetime Cohort Study (SJLIFE). *Lancet*. 2017;390(10112):2569-2582. https://doi.org/10.1016/S0140-6736(17)31610-0
5. Dixon SB, Liu Q, Chow EJ, et al. Specific causes of excess late mortality and association with modifiable risk factors among survivors of childhood cancer: a report from the Childhood Cancer Survivor Study cohort. *Lancet*. 2023;401(10386):1447-1457. https://doi.org/10.1016/S0140-6736(22)02471-0
6. Kremer LCM, Mulder RL, Oeffinger KC, et al. A worldwide collaboration to harmonize guidelines for the long-term follow-up of childhood and young adult cancer survivors: a report from the International Late Effects of Childhood Cancer Guideline Harmonization Group. *Pediatr Blood Cancer*. 2013;60(4):543-549. https://doi.org/10.1002/pbc.24445
7. Hodgson DC, Cotton C, Crystal P, et al. Impact of early breast cancer screening on mortality among young survivors of childhood Hodgkin's lymphoma. *J Natl Cancer Inst*. 2016;108(7):djw010. https://doi.org/10.1093/jnci/djw010
8. van Santen HM, Chemaitilly W, Meacham LR, et al. Endocrine health in childhood cancer survivors. *Pediatr Clin North Am*. 2020;67(6):1171-1186. https://doi.org/10.1016/j.pcl.2020.08.002
9. Chemaitilly W, Cohen LE, Mostoufi-Moab S, et al. Endocrine late effects in childhood cancer survivors. *J Clin Oncol*. 2018;36(21):2153-2159. https://doi.org/10.1200/JCO.2017.76.3268
10. Chemaitilly W, Cohen LE. Diagnosis of endocrine disease: endocrine late-effects of childhood cancer and its treatments. *Eur J Endocrinol*. 2017;176(4):R183-R203. https://doi.org/10.1530/EJE-17-0054
11. Clement SC, Kremer LCM, Verburg FA, et al. Balancing the benefits and harms of thyroid cancer surveillance in survivors of childhood, adolescent and young adult cancer: recommendations from the international late effects of childhood cancer guideline harmonization group in collaboration with the PanCareSurFup consortium. *Cancer Treat Rev*. 2018;63:28-39. https://doi.org/10.1016/j.ctrv.2017.11.005
12. van Iersel L, Mulder RL, Denzer C, et al. Hypothalamic-pituitary and other endocrine surveillance among childhood cancer survivors. *Endocr Rev*. 2022;43(5):794-823. https://doi.org/10.1210/endrev/bnab040
13. Gebauer J, Higham C, Langer T, et al. Long-term endocrine and metabolic consequences of cancer treatment: a systematic review. *Endocr Rev*. 2019;40(3):711-767. https://doi.org/10.1210/er.2018-00092
14. Erdmann F, Wellbrock M, Trübenbach C, et al. Incidence patterns and temporal trends of childhood cancer in Germany,

1980-2019: forty years of childhood cancer registration in Germany. *Int J Cancer*. 2025;158(6):1541-1554. https://doi.org/10.1002/ijc.70167
15. Aleshchenko E, Swart E, Spix C, et al. Long-term care, care needs and wellbeing of individuals after cancer in childhood or adolescence (VersKiK): study protocol of a large scale multi-methods non-interventional study. *BMC Health Serv Res*. 2022;22(1):1176. https://doi.org/10.1186/s12913-022-08549-3
16. Aleshchenko E, Apfelbacher C, Baust K, et al. Verskik: study protocol of an observational registry-based study on the current state of follow-up care and adherence to follow-up guidelines after cancer in childhood or adolescence. *Cancer Epidemiol*. 2023;87:102469. https://doi.org/10.1016/j.canep.2023.102469
17. Merzenich H, Ihle P, Küpper-Nybelen J, et al. Bildung einer Kohorte zur Untersuchung der medizinischen Versorgung nach einer Krebserkrankung im Kindes- oder Jugendalter (VersKiK-Kohorte) mittels Record-Linkage zwischen Deutschem Kinderkrebsregister und gesetzlichen Krankenkassen. *Gesundheitswesen*. 2025;87(S 02):S254-S259. https://doi.org/10.1055/a-2536-2966
18. Epping J, Stahmeyer JT, Tetzlaff F, Tetzlaff J. M2q oder doch etwas Anderes? Der Einfluss verschiedener Aufgreifkriterien auf die Prävalenzschätzung chronischer Erkrankungen mit ambulanten GKV-Diagnosedaten. *Gesundheitswesen*. 2024;86(S 03):S188-S195. https://doi.org/10.1055/a-2052-6477
19. Streefkerk N, Teepen JC, Feijen EAM, et al. The cumulative burden of self-reported, clinically relevant outcomes in long-term childhood cancer survivors and implications for survivorship care: a DCCSS LATER study. *Cancer*. 2024;130(8):1349-1358. https://doi.org/10.1002/cncr.35148
20. Mostoufi-Moab S, Seidel K, Leisenring WM, et al. Endocrine abnormalities in aging survivors of childhood cancer: a report from the childhood cancer survivor study. *J Clin Oncol*. 2016;34(27):3240-3247. https://doi.org/10.1200/JCO.2016.66.6545
21. Brignardello E, Felicetti F, Castiglione A, et al. Endocrine health conditions in adult survivors of childhood cancer: the need for specialized adult-focused follow-up clinics. *Eur J Endocrinol*. 2013;168(3):465-472. https://doi.org/10.1530/EJE-12-1043
22. Chemaitilly W, Li Z, Brinkman TM, et al. Primary hypothyroidism in childhood cancer survivors: prevalence, risk factors, and long-term consequences. *Cancer*. 2022;128(3):606-614. https://doi.org/10.1002/cncr.33969
23. Heinzel A, Müller D, van Santen HM, Clement SC, Schneider AB, Verburg FA. The effect of surveillance for differentiated thyroid carcinoma in childhood cancer survivors on survival rates: a decision-tree-based analysis. *Endocr Connect*. 2022;11(12):e220092. https://doi.org/10.1530/EC-22-0092
24. Chemaitilly W, Li Z, Huang S, et al. Anterior hypopituitarism in adult survivors of childhood cancers treated with cranial radiotherapy: a report from the St Jude Lifetime Cohort study. *J Clin Oncol*. 2015;33(5):492-500. https://doi.org/10.1200/JCO.2014.56.7933
25. van Atteveld JE, Mulder RL, van den Heuvel-Eibrink MM, et al. Bone mineral density surveillance for childhood, adolescent, and young adult cancer survivors: evidence-based recommendations from the International Late Effects of Childhood Cancer Guideline Harmonization Group. *Lancet Diabetes Endocrinol*. 2021;9(9):622-637. https://doi.org/10.1016/S2213-8587(21)00173-X
26. Bolier M, de Winter DTC, Fiocco M, et al. Prevalence and determinants of diabetes mellitus in 2,338 long-term Dutch childhood cancer survivors (DCCS-LATER2 Study). *J Clin Endocrinol Metab*. 2025;110(10):e3259-e3270. https://doi.org/10.1210/clinem/dgaf078
27. Molony C, Pollock N, Mostoufi-Moab S, et al. Endocrine late effects: consequence or catalyst to health disparities in childhood cancer survivors? *Endocrinol Metab Clin North Am*. 2025;54(2):307-314. https://doi.org/10.1016/j.ecl.2025.02.017