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Pediatric neurosurgery in Ukraine in 2001-2020. Availability, workforce, performance indicators

Vira A. Vasyuta ¹, Mykola Y. Polishchuk ², Anna N. Nikiforova ³, Tetyana A. Yovenko ³, Svitlana A. Verbovska ¹, Oksana M. Goncharuk ²

¹ Scientific and Organizational Department, Romodanov Neurosurgery Institute, Kyiv, Ukraine

² Department of Neurosurgery, Shupyk National Healthcare University of Ukraine, Kyiv, Ukraine

³ Department of Medical Statistics, Romodanov Neurosurgery Institute, Kyiv, Ukraine

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Address for correspondence:

Anna N. Nikiforova, Department of Medical Statistics, Romodanov Neurosurgery Institute, 32 Platona Mayborody St., Kyiv, 04050, Ukraine, e-mail: anna.neuro@gmail.com

Objective: to analyze the development dynamics of pediatric neurosurgical care in Ukraine in 2001-2020.

Materials and methods. The number of pediatric neurosurgical beds, pediatric neurosurgeons, hospitalization rates and surgical treatment of children in neurosurgical departments of Ukraine in 2001-2020 were analyzed. Data for the years 2014-2020 were unavailable for departments located in temporarily non-government-controlled territories.

Results. In 2020, there were 22 pediatric neurosurgery departments in Ukraine, with a total of 290 pediatric neurosurgical beds, representing a 26.6% increase compared to 2001. Pediatric neurosurgical departments or pediatric units with neurosurgical beds were operational in almost all regions. The distribution of pediatric neurosurgical beds in Ukraine did not statistically differ from countries with high-income levels ($p=0.9987$). The increased number of beds contributed to more than doubling the provision of neurosurgical beds per child population. In 2001, there were 17 beds per 1 million children, compared to 38 beds in 2020.

In 2020, the number of pediatric neurosurgeons in Ukraine doubled compared to 2001 reaching 58 in 2020 (9.2% of the total number of neurosurgeons in Ukraine and 2.5% of the total number of pediatric neurosurgeons globally). The provision of pediatric neurosurgeons in Ukraine increased more than threefold from 2001 to 2020, reaching 7.7 per 1 million children, meeting the Ministry of Health of Ukraine's standard (7.5). Consequently, the workload per pediatric neurosurgeon decreased almost fourfold, with one specialist per 129,895 children.

In 2020, the number of children hospitalized in neurosurgical departments was 9,045, operated on – 3,144, representing a 15.8% decrease and a 3.3% increase, respectively compared to 2001. Per 1 million child population, the hospitalization rate increased by 53, 8% (1201 and 781), the surgery rate increased by 88.7% (417 and 221).

Despite the decrease in the number of operated patients over 20 years, surgical activity in neurosurgical institutions of the country increased from 28.3% in 2001 to 34.8% in 2020 (by 23%), postoperative lethality during this period decreased from 2,1 to 1.0% (by 52%).

Significant fluctuations in hospital morbidity (HM) rate of children for general neurosurgical pathology and its individual types were recorded during the studied period. In 2020, an increase in these indicators was noted compared to 2001: HM for pediatric neurosurgical pathology in general increased by 53.7% (from 781 to 1,201 cases per 1 million child population), for acute craniocerebral trauma - by 17,5% (from 595 to 699), for hydrocephalus - 5.1 times (from 29 to 149), for neuro-oncological diseases - 3.2 times (from 31 to 100), for congenital anomalies of the nervous system - 4 times (from 15 to 60), for vascular lesions of the nervous system - 5.1 times (from 5 to 26), for acute spinal trauma - twice (from 9 to 18).

Conclusions. Ukraine is a country with high availability of pediatric neurosurgical care. Over the past 20 years, there has been an increase in the provision of pediatric neurosurgery beds and pediatric neurosurgeons. In the first 13 years of the 21st century the trend towards a significant increase in both absolute and relative rates of hospitalization and surgery for children with neurosurgical pathology in subsequent years as a result of the annexation of Crimea, military actions in Donbas and the coronavirus epidemic has changed to a trend towards a decrease in these rates. However, in general, only the absolute number of hospitalized children decreased over 20 years, while the absolute number of operated on and the level of hospitalization and operated on increased. Surgical activity also increased accompanied by a decrease in postoperative lethality.

Keywords: *pediatric neurosurgery; pediatric neurosurgical beds; pediatric neurosurgeons; pediatric neurosurgical pathology; hospital morbidity*

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Introduction

The first pediatric neurosurgery department in Ukraine began providing assistance in 1950 as part of the newly established Kyiv Institute of Neurosurgery. The department was entrusted with organizational and methodical work on the creation and development of pediatric neurosurgical service in the country. Initial research focused on studying the clinical course and surgical treatment of brain tumors in children as well as the surgical treatment of congenital malformations of the central and peripheral nervous system. The treatment of cholesteatomas, craniostenoses, hydrocephalus, birth-related craniocerebral injuries, spinal cord tumors and chronic subdural hematomas in infants has been successfully studied. Technological advances allowed for the expansion of surgical interventions for critical cases of hydrocephalus and brain tumors in infants. Emergency care for newborns with ruptured spinal cord hernias was organized and distributed in Ukraine. The number of patients with such pathologies as neurorachischisis, intramedullary tumors, tumors of the brainstem, III ventricle, and pineal area has increased significantly [1, 2].

The pediatric neurosurgical service of Ukraine actually began to be formed in accordance with the order of the Ministry of Health of Ukraine No.360 dated December 19, 1997 "On complementing the list of medical positions with the position of "pediatric neurosurgeon". At that time, there were 4 pediatric neurosurgical departments (111 beds) and 2 departments of a different profile with pediatric neurosurgical beds (20 beds) in the country. Subsequently, orders No.224 dated September 10, 1999 "On the improvement of neurosurgical care for children in Ukraine" and No.33 dated February 23, 2000 "On staff standards and typical staffing of health care institutions" were issued. Specialization and advanced training courses in the field of "pediatric neurosurgery" have been held in the departments of neurosurgery, specialists have been certified and re-certified, regional pediatric neurosurgical departments and pediatric neurosurgical beds in departments of other specialties have been opened, the service of the main pediatric neurosurgeons of the country was established, standards for the provision of pediatric neurosurgical beds and by specialists of the country's population, the workload on the specialist and surgical activity have been determined.

Currently, Ukraine has a powerful pediatric neurosurgical service training highly qualified specialists. The range of pathologies that are subject to neurosurgical treatment has been significantly expanded, and the capabilities and quality of neurosurgical care for children have been enhanced. Pediatric neurosurgeons are proficient in treating the entire spectrum of pediatric pathologies including congenital central nervous system defects, hydrocephalus, brain and spinal cord tumors, inflammatory and vascular diseases of the central nervous system, brain and spinal cord injuries.

Objective: to analyze the development dynamics of pediatric neurosurgical care in Ukraine in 2001-2020.

Materials and methods

Study object

The number of pediatric neurosurgical beds, pediatric neurosurgeons, hospitalization rates and surgical treatment of children in neurosurgical departments of Ukraine in 2001–2020 were analyzed. Data from departments located in temporarily uncontrollable territories are missing for the years 2014-2020.

Inclusion criteria

Data from pediatric neurosurgical departments and departments of a different profile, which include pediatric neurosurgical beds, were included in the study.

Study design

Accounting of neurosurgical units (beds) in Ukraine was carried out according to the form approved by the order of the Ministry of Health of Ukraine No. 295 dated November 24, 1994. The form regulates the accounting of neurosurgical beds, staff, hospitalized, operated on and deceased children according to the main nosological forms, according to which neurosurgical treatment is carried out.

From the neurosurgical departments and departments of another profile providing neurosurgical care were selected, which contain pediatric neurosurgical beds and pediatric neurosurgeons providing neurosurgical care to children.

From the array of statistical data on the provision of neurosurgical care, data on children who were hospitalized, operated on, and died as a result of neurosurgical pathology were selected.

The pediatric population includes children under 18 years of age.

Data on the number of pediatric population were obtained partly from the source [3] and from the website of the Institute of Youth <https://inmol.org/stat/children-count-ua/>. Based on these data, the trend line $y=0,0172x^2-0,06902x+14,429$ was determined. Missing data for some years were calculated with R-squared value $R^2=0,9993$.

Statistical analysis

Relative indicators were calculated: surgical activity, overall and postoperative lethality. Statistical processing of data was carried out using the analysis of dynamic series using the grouping method. Prognostic models were constructed. To compare the distribution of pediatric beds in Ukraine with high-income countries, the chi-square criterion was used. The critical level of statistical significance (p) for hypothesis testing was considered to be ≤ 0.05 . Microsoft Excel software was used for calculations.

Results and discussion

Beds and workforce

In 2001, 6 pediatric neurosurgical departments (153 beds) and 10 other pediatric units (76 pediatric neurosurgical beds) provided neurosurgical care to children in Ukraine. The establishment of pediatric neurosurgery as a separate profession in 1997 and the Ministry of Health of Ukraine's directive to improve the provision of pediatric neurosurgical care contributed to the expansion of the pediatric neurosurgical hospital stock. In 2013, there

This article contains some figures that are displayed in color online but in black and white in the print edition.

were already 8 pediatric neurosurgery departments (189 beds) and 14 departments of other profiles with pediatric neurosurgery beds (114 beds) operating in the country. The total number of pediatric neurosurgical beds was 2.3 times higher than in 1997 and 32.3% higher than in 2001. In the following years, the hospital stock of the pediatric neurosurgical network was influenced by political and epidemiological factors. In 2014, a decrease in almost all indicators was recorded by 8.3–16.2%, with the exception of the level of workload for 1 pediatric neurosurgeon, which increased by 14.3% (**Fig. 1, Table 1**). In the next 6 years, an increase in the hospital stock was noted, but due to the quarantine in 2020, part of the pediatric neurosurgical stock was repurposed for covid beds. In 2020, Ukraine had 22 pediatric neurosurgery departments with a total of 290 pediatric neurosurgery beds (26.6% more than in 2001) (**see Fig. 1, Table 1**).

J.T. Roach et al. conducted a study based on an online survey of members of the International Society for Pediatric Neurosurgery, aiming to assess the availability of pediatric neurosurgical care in different countries. The dependence of available resources on the country's income level has been established. Low- and middle-income countries tend to concentrate pediatric neurosurgical beds in large cities, while high-income countries tend to have more units, but with fewer beds, which are evenly distributed throughout the country, making neurosurgical care for children more accessible. Thus, out of 96 pediatric neurosurgical departments in high-income countries, 42 (43.8%) had less than 10 beds, 37 (38.5%) had 10–20 beds, 13 (13.5%) had 21–40 beds, 4 (4.2%) – more than 40 beds [4].

Ukraine is a country with high availability of pediatric neurosurgical care. Pediatric neurosurgical departments or pediatric units of a different profile,

which include pediatric neurosurgical beds, operate in almost all regions, with 10 (45.5%) having fewer than 10 beds, 8 (36.4%) having 10–20 beds, 3 (13.6%) having 21–40 beds and 1 (4.5%) having more than 40. The distribution of pediatric neurosurgical beds in Ukraine is not statistically different from that in high-income countries ($p=0.9987$).

The expansion of bed capacity led to more than a doubling of the indicator measuring the availability of neurosurgical beds for children. In 2001, there were 17 beds per million children, compared to 38 in 2020. In the literature, neither global standards nor indicators of the availability of pediatric neurosurgical beds in other countries have been found, so it is impossible to find out the level of their sufficiency. According to the standard of the Ministry of Health of Ukraine (75 beds per 1 million child population), which has not been in effect since 2016, the child population of Ukraine is provided with pediatric neurosurgical beds by half (**see Fig. 1, Table 1**).

Over the first 13 years of the 21st century, the number of pediatric neurosurgeons and their availability to the pediatric population of Ukraine varied with a clear upward trend. The events of 2013–2014 had a negative impact on child neurosurgical personnel, with the number of doctors decreasing by 16.2% (from 68 to 57 individuals). Over the following 6 years, the number of pediatric neurosurgeons and their provision to the pediatric population remained stable (**Fig. 2**). In 2020, the number of pediatric neurosurgeons in Ukraine doubled compared to 2001, reaching 58 (9.2% of the total number of neurosurgeons in Ukraine and 2.5% of the total number of pediatric neurosurgeons globally). Currently, there are 2297 pediatric neurosurgeons working in the world, 85.6% of whom work in high-income and upper-middle-income countries [5].

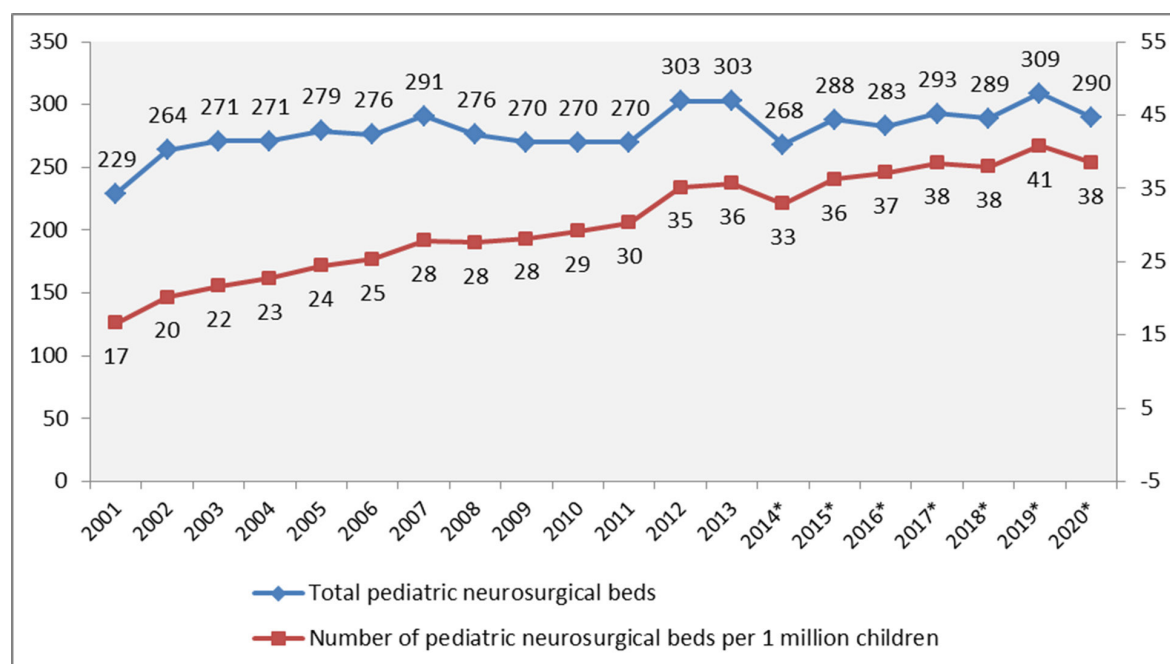


Fig. 1. The total number of pediatric neurosurgical beds and density of pediatric neurosurgical beds (standardized to per 1 mln child population)

Note. * Hereinafter in the text excluding the data of departments located in temporarily uncontrolled territories.

Table 1. Pediatric neurosurgical hospital stock, number of pediatric neurosurgeons and availability of pediatric neurosurgeons in the pediatric population

Indicator	2001	2013	2014*	Growth rate 2013/2001, %	2019	2020	Growth rate 2020/2019, %	Growth rate 2020/2001, %
Number of pediatric neurosurgical departments	6	8	7	133,3	8	8	100,0	133,3
Number of beds they have	153	189	169	123,5	200	196	98,0	128,1
Number of departments of other profiles with pediatric neurosurgical beds	10	14	12	140,0	14	14	100,0	140,0
Number of beds they have	76	114	99	150,0	109	94	86,2	123,7
Total pediatric neurosurgical beds	229	303	268	132,3	309	290	93,8	126,6
Number of pediatric neurosurgeons	28	68	57	242,9	57	58	101,7	207,1
Number of pediatric neurosurgeons per 1 million children	2,0	8,0	7,0	400,0	7,5	7,7	102,7	385,0
1 pediatric neurosurgeon per children	491 321	125 000	142 870	25,4	132 977	129 895	97,7	26,4
Number of pediatric neurosurgical beds per 1 million children	17	36	33	211,8	41	38	92,7	223,5

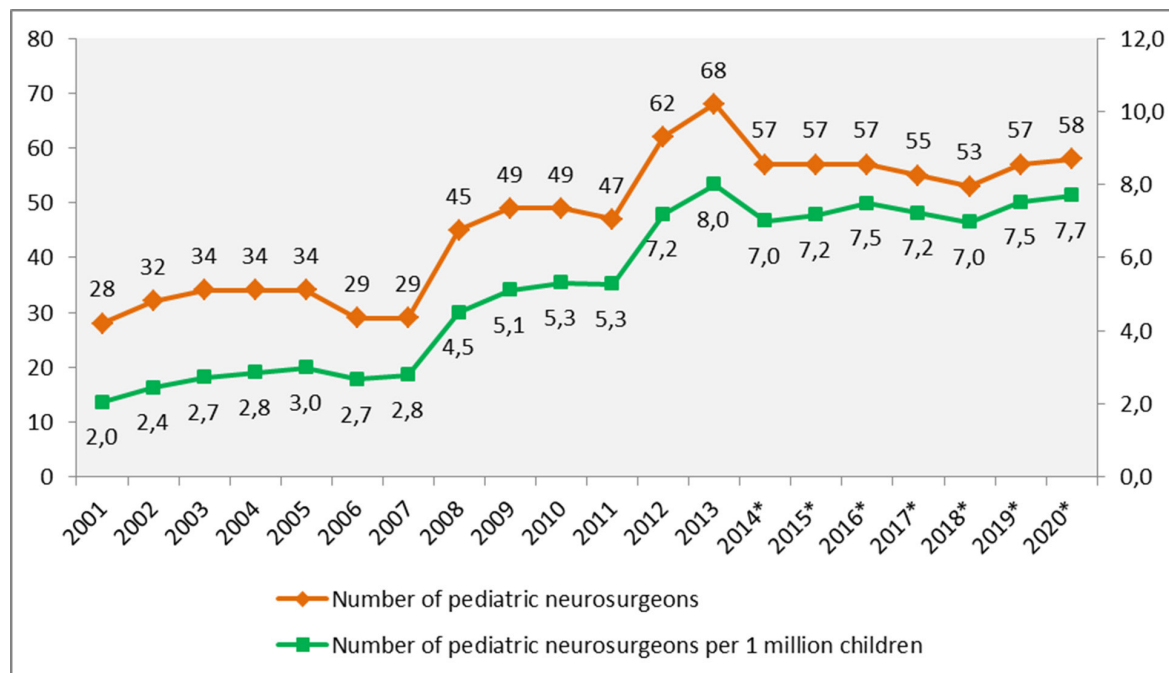


Fig. 2. The total number of pediatric neurosurgeons and density of pediatric neurosurgeons (standardized to per 1 mln child population)

According to the standards of the Ministry of Health of Ukraine, 7.5 child neurosurgeon rates are required for 1 million children, i.e. for 1 pediatric neurosurgeon - about 120,000 children. In 2020, the number of pediatric neurosurgeons met the standard (7.7 per 1 million children) and was more than 3 times higher than in 2001 (see Table 1, Fig. 2). Accordingly, the workload of 1 pediatric neurosurgeon decreased almost 4 times – 1298,95 children. In low-income African countries, the number of pediatric neurosurgeons is about 1 per 30 million children [5], in the USA - 1 per 289,799 people under the age of 24 [6].

Pediatric neurosurgery training

In the 1950s-1990s, there was no separate specialty "pediatric neurosurgery", and training the basics of neurosurgical care for children was conducted as a part of the general training of neurosurgeons. The clinical residency program of the Institute of Neurosurgery provided that each resident medical practitioner should undergo practical training in all clinics of the institute (oncology, vascular pathology, neurotrauma, spinal pathology, pediatric neurosurgery), as well as in other divisions of the institute (morphology, radiology, etc.). In clinical divisions, training was not regulated by terms. In the pediatric clinic, residents worked with future employment in mind, there were no separate programs. During the 5-month specialization courses in neurosurgery, lectures on the peculiarities of pediatric pathology were delivered. The lecturers of the Department of Neurosurgery at Kyiv Institute of Postgraduate Education (now P.L. Shupyk National Healthcare University of Ukraine) introduced the pediatric department, and sometimes the trainees were involved in the department's work.

With the introduction of internship in 1993 (3 years of training in neurosurgery), the principle remained the

same, but the number of lectures increased and interns had more opportunities to familiarize themselves with the work of the departments, particularly the pediatric one. Since 1996, the training period for neurosurgeons has been reduced to one and a half years. At the end of 1997, the list of medical positions was supplemented with the position of "pediatric neurosurgeon". The training program for pediatric neurosurgeons included 9 months of general specialization in neurosurgery and 6 months of pediatric neurosurgery. In 2005, by the decision of the Ministry of Health of Ukraine, internship in neurosurgery and all surgical disciplines became 3-year internship. The principle of training has not changed. Students could focus on the areas they identified after the second year of training.

Since 2010, constant work has been carried out to increase the terms and principles of neurosurgeon training according to the standards of the European Association of Neurosurgeons (5–7 years), depending on the direction and involvement in scientific work. The Ministry of Health of Ukraine issued an order on the 5-year training of neurosurgeons: internship, upon completion of which a specialist certificate was issued, and a recommended 2-year residency with the opportunity to improve knowledge in a particular area (pediatric neurosurgery, vascular, spinal, etc.). This principle lasted for a year, since almost all of them having received a certificate, were employed because they had good training.

In 2020–2023, unclear changes occurred in post-graduate training in neurosurgery, particularly in pediatric neurosurgery. According to the orders of the Ministry of Health of Ukraine, specialization in adult neurosurgery requires 9 months with a certificate of trauma surgeon, and specialization in pediatric neurosurgery – 6 months with a certificate of pediatric surgeon.

In 2023, a 6-year residency program in neurosurgery was developed by the Department of Neurosurgery of Shupyk National Healthcare University of Ukraine, Romodanov Neurosurgery Institute, Kyiv, Ukraine, together with the Ukrainian Neurosurgical Association and the Department of Medical Personnel, Education and Science of the Ministry of Health of Ukraine. The decision to implement it in Ukraine starting in 2024 was made at the Ministry of Health of Ukraine's staff meeting on January 13, 2024.

The principles of training neurosurgeons under the 6-year program meet European standards. The program includes mandatory resident rotation, in particular, work in a neurosurgical clinic. The residency will become a pilot project of modern postgraduate education in our country. The training will be held at the Department of Neurosurgery of Shupyk National Healthcare University of Ukraine, with educational bases at Romodanov Neurosurgery Institute and neurosurgical departments certified by the Ministry of Health of Ukraine.

In Europe, there is no "pediatric neurosurgery" specialty, it is a subspecialty. Training and improvement of technologies and techniques of pediatric neurosurgery are recommended to be carried out in specialized centers.

Pediatric neurosurgical care

In the pediatric neurosurgical departments, assistance was provided to children with craniocerebral and spinal injuries, brain and spinal cord tumors, vascular diseases of the nervous system, hydrocephalus, congenital malformations of the central nervous system. The emergence of new technologies and diagnostic and treatment methods contributes to the rapid development of pediatric neurosurgery. The use of new developments improves the outcomes of surgical interventions and reduces the number of adverse and fatal consequences.

In the first 13 years of the 21st century a clear trend towards an increase in the number of hospitalized and operated patients was noted. Thus, compared to 2001, the number of hospitalized children increased by 33.9% (per 1 million child population - 2.2 times), the number of operated on by 66.4% (per 1 million child population - 2.7 times). The annexation of Crimea and the occupation of Donbass in 2014 led to a decrease in the number of hospitalized patients by 14.7% (per 1 million child population - by 11%), and operated on - by 17.4% (per 1 million child population - by 13.8%). The following five years, fluctuations in indicators with a slight upward trend were recorded, but the quarantine announced in 2020 resulted in a significant decrease in the number of hospitalizations and neurosurgical care for children - by 24.8% (per 1 million child population - by 24.3 %) and 18.4% (per 1 million child population - 18.1%), respectively (**Table 2, Figs. 3 and 4**).

The COVID-19 pandemic has led to a decrease in the number of neurosurgical operations worldwide [7–9]. This concerned many nosologies, but most of all - traumatic injuries of the nervous system, hydrocephalus, epilepsy. This pattern has been attributed to travel restrictions and stay-at-home orders, reducing the likelihood of traumatic injuries such as car accidents and sports injuries, people's attempts to avoid hospitals, postponing elective surgeries due to limited hospital resources as a result of the repurposing of hospital beds to COVID ones.

Analyzing the dynamics as a whole for 20 years, only the absolute number of hospitalized patients decreased (by 15.8%), while the absolute number of operated patients increased by 3.3%. Regarding the relative indicators (per 1 million children), the hospitalization rate increased by 53.8%, and the surgical rate increased by 88.7% (**see Table 2, Figs. 3 and 4**).

Table 2. Indicators of pediatric neurosurgical care, utilization of hospital stock and workload of pediatric neurosurgeons

Indicator	2001	2005	2010	2015*	2019*	2020*	Growth rate 2019/2001, %	Growth rate 2020/2019, %
Number of hospitalized children	10 741	12 392	12 685	12 546	12 031	9 045	112,0	84,2
Number of hospitalized children per 1 million child population	781	1086	1372	1577	1587	1201	203,2	153,8
Number of operated children	3044	3862	4476	4001	3855	3144	126,6	103,3
Number of operated children per 1 million child population	221	339	484	503	509	417	230,3	188,7
Surgical activity, %	28,3	31,2	35,3	31,9	32,0	34,8	113,1	123,0
Died	102	95	113	77	43	40	42,2	39,2
Total lethality, %	0,9	0,8	0,9	0,6	0,4	0,4	44,4	44,4
Died after surgery	65	70	74	58	36	31	55,4	47,7
Postoperative lethality, %	2,1	1,8	1,7	1,4	0,9	1,0	42,9	47,6
Number of surgeries per 1 pediatric bed	13,3	13,8	16,6	13,9	12,5	10,8	94,0	86,4
Number of surgeries per 1 pediatric neurosurgeon	95,1	113,6	91,3	70,2	67,6	54,2	71,1	80,2

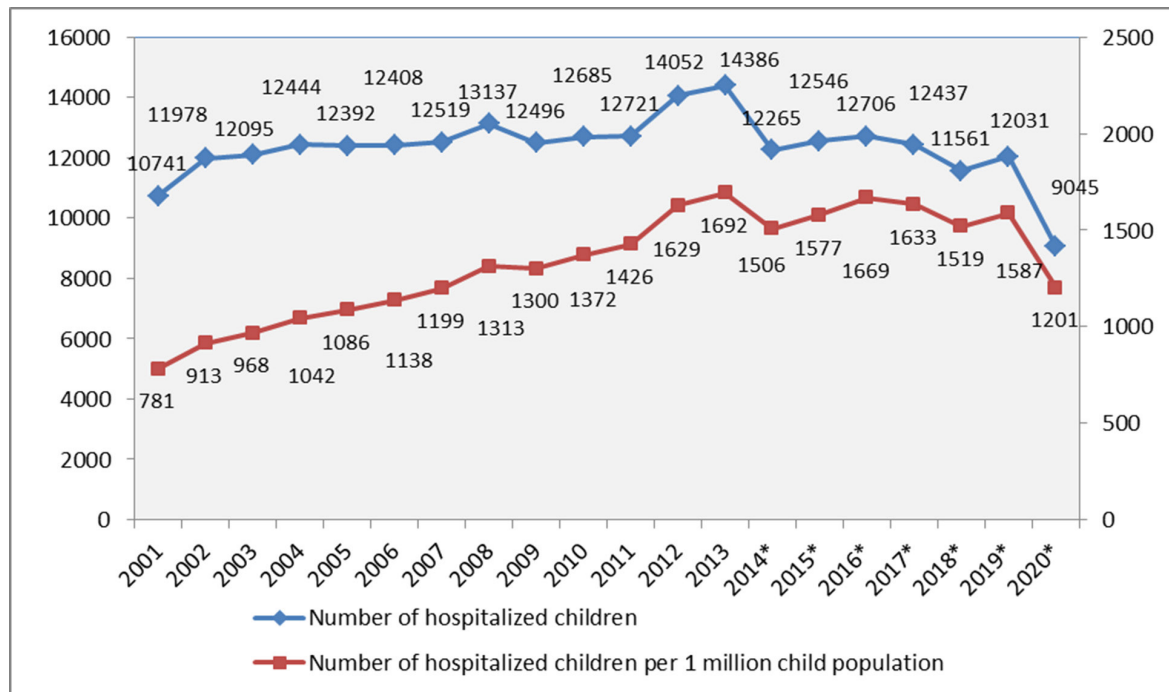


Fig. 3. Hospitalization rates for children with neurosurgical pathology

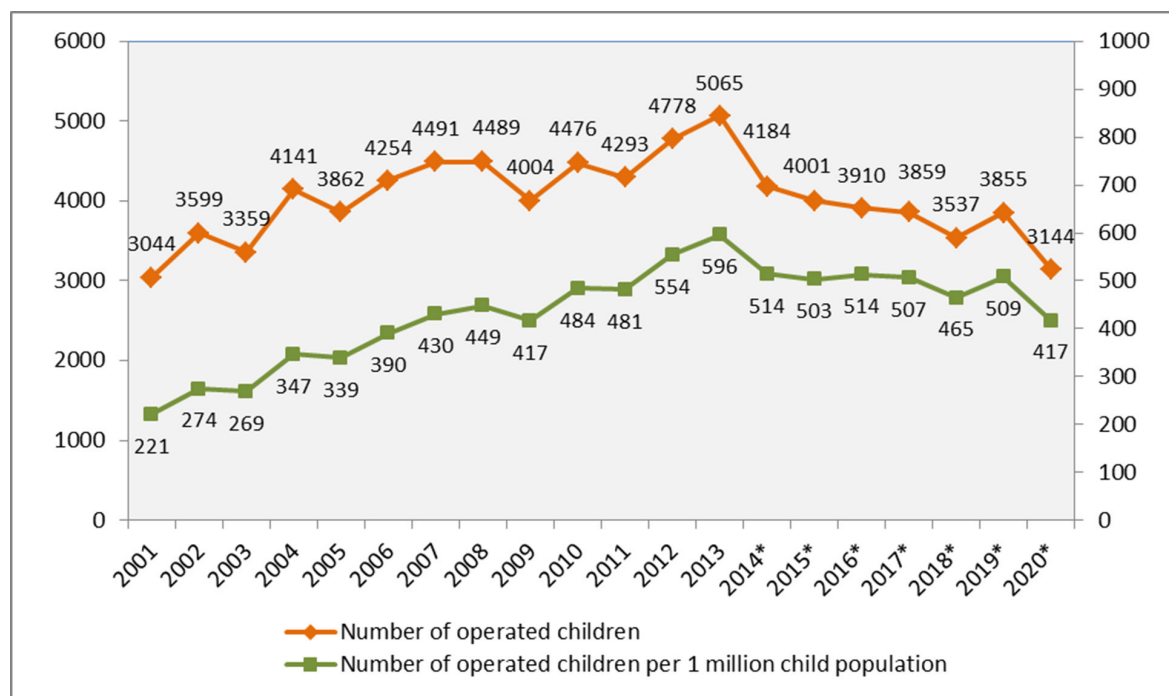


Fig. 4. Rates of operated children with neurosurgical pathology

Analysis of hospital morbidity (HM) was conducted, calculated as the number of hospitalized patients with pediatric neurosurgical pathology per year, divided by the number of pediatric population and multiplied by 1 million. The HM indicator can to some extent assess the prevalence of pathology and determine its development dynamics [10].

Over 20 years, the HM for pediatric neurosurgical pathology, both overall and for specific types of

pathology, has changed. Until 2014, a significant increase in HM was recorded, in subsequent years, due to military actions in eastern Ukraine, the annexation of Crimea, and the COVID-19 pandemic, HM varied.

The total HM for a child with neurosurgical pathology has reached its peak in 2013 and was 1692 cases per 1 million child population, which is 2.2 times higher than in 2001. Over the next 5 years, the rate ranged from 1500-1600 before dropping sharply to 1201 in 2020 (Fig. 5).

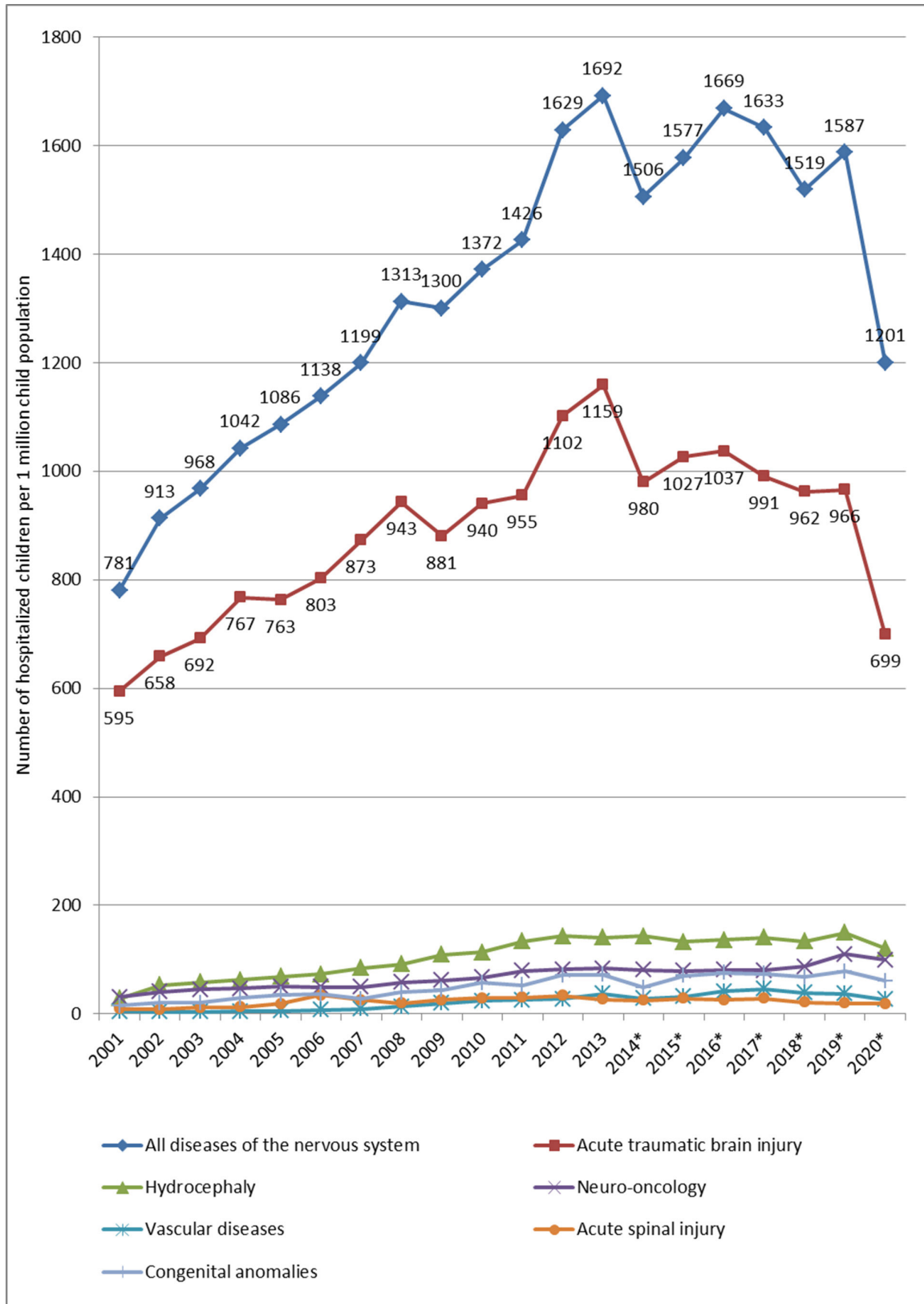


Fig. 5. Hospital incidence of pediatric neurosurgical pathology

The most common neurosurgical pathology in children is acute craniocerebral trauma (Fig. 7), despite the fact that its proportion in the total structure has decreased from 76.2 to 58.2% over 20 years. In 2001, 595 children with this pathology were hospitalized, in

neurological institutions in Ukraine per 1 million child population. Until 2013 this figure has almost doubled (up to 1159). In the next 5 years, it was about 1000, in 2020 – decreased to the level of 2003. (699 per 1 million child population) (Fig. 5).

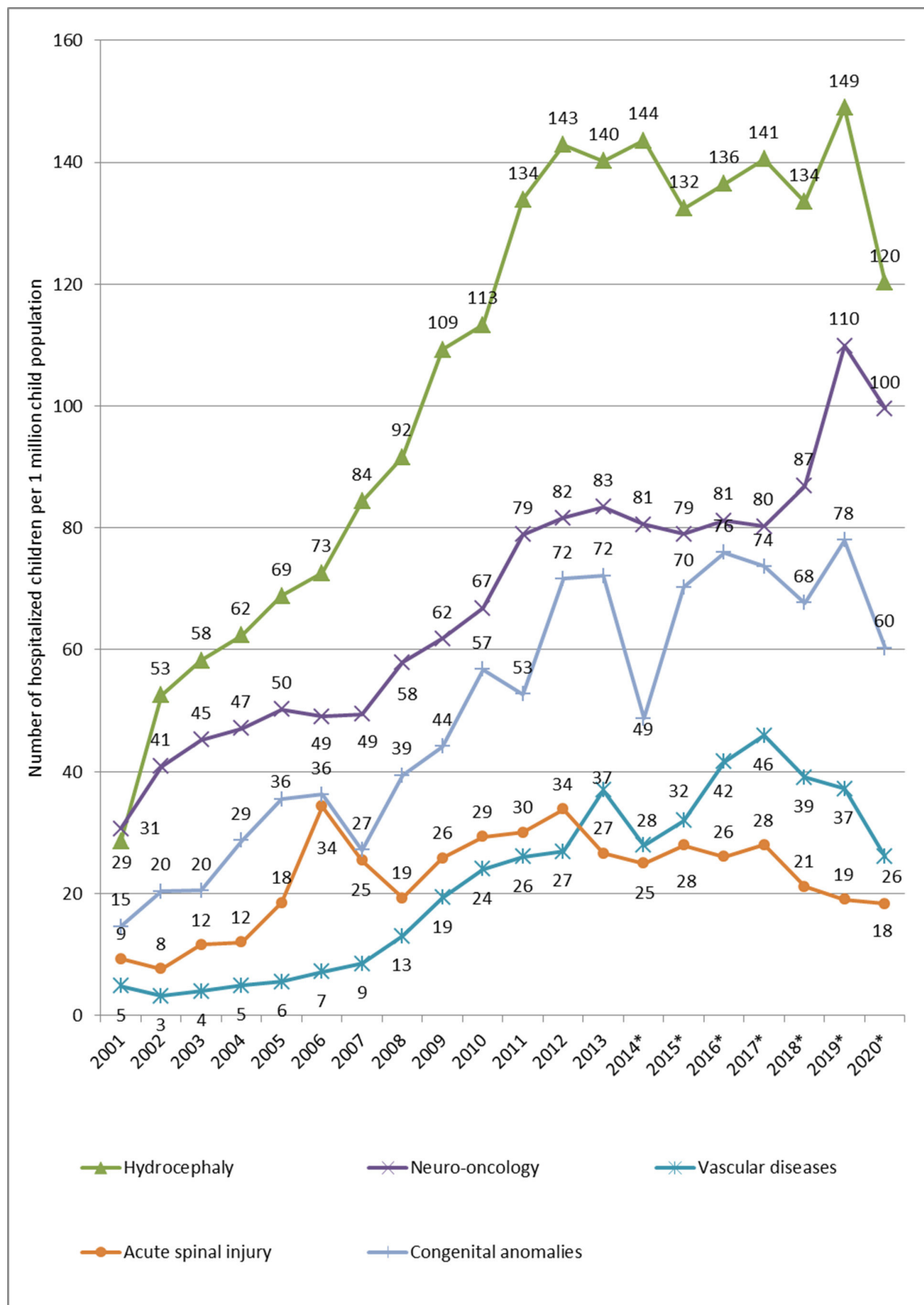


Fig. 6. Hospital incidence by major types of pediatric neurosurgical pathology

Fig. 5 demonstrates that other types of pediatric neurosurgical pathology are much less frequently recorded. The second most common pediatric neurosurgical pathology is hydrocephalus (see Fig. 7).

Over 20 years, the proportion of this pathology in the overall structure has increased from 3.7 to 10.0%, leading to an increase in HM from 29 to 149 per 1 million child population (Fig. 6). This is explained not

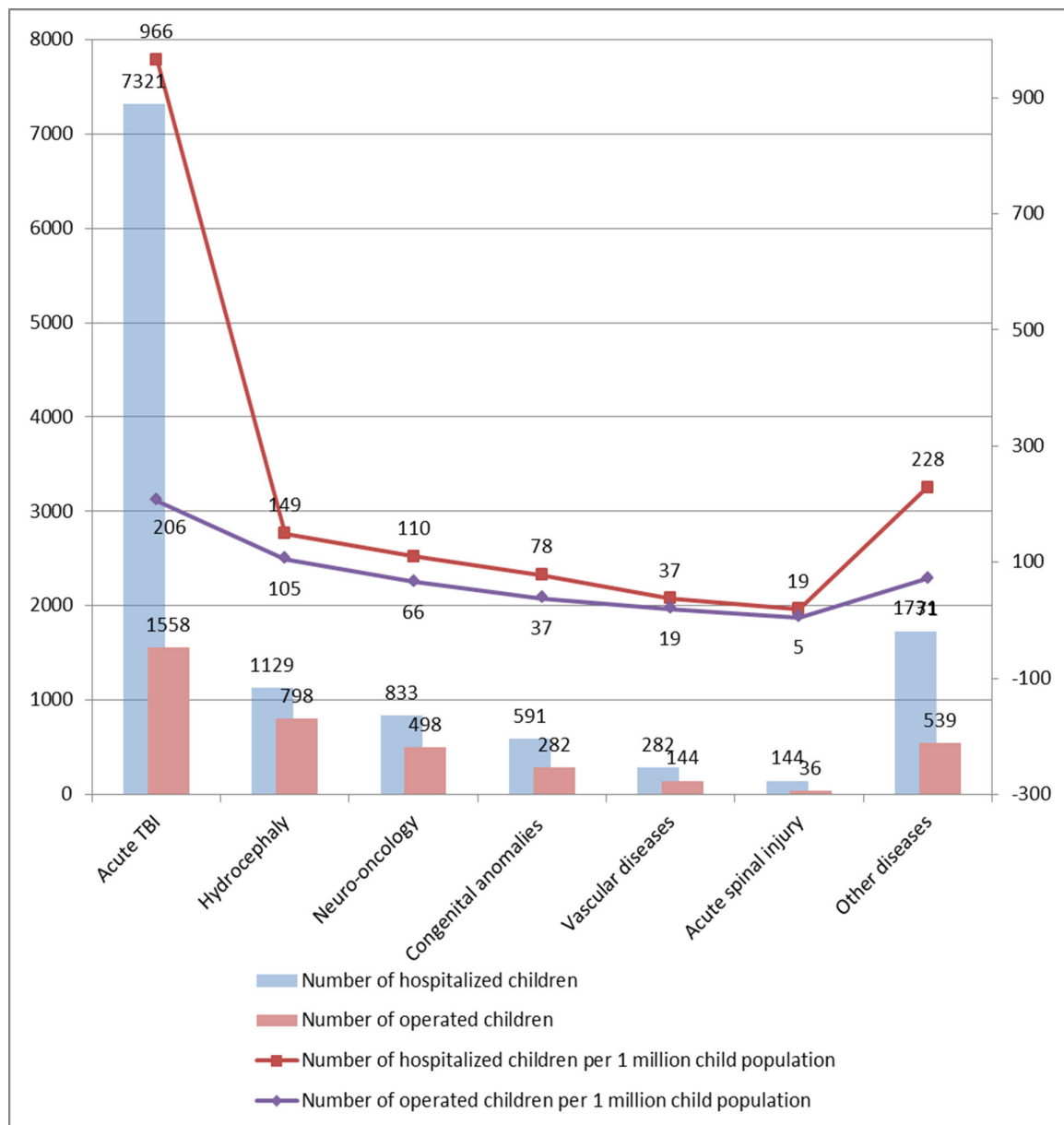


Fig. 7. Absolute and calculated per 1 million child population, the number of children treated and operated on for neurosurgical pathology in 2019.

Notes. TBI- traumatic brain injury.

2019 was chosen to demonstrate the indicators, since the indicators of 2020 were significantly influenced by quarantine measures, altering the established trends

by the increase in the number of pathologies, but by the development of hydrocephalus treatment technologies.

A significant increase in HM for neuro-oncological diseases was also noted. From 2001 to 2013, the annual growth rate of this indicator was 4 cases per 1 million population (from 31 to 83). In subsequent years, the relative stability of the indicator (79–81 cases) was observed with a significant increase in 2019 to 110 and a further decrease to 100 due to the COVID-19 pandemic in 2020 (see Fig. 6). In the overall structure of pediatric neurosurgical pathology, the proportion of neuro-oncological diseases increased from 3.9 to 8.3% ranking the 3rd (see Fig. 7).

Congenital anomalies of the nervous system rank 4th in the structure of the pediatric population hospitalized in

neurosurgical departments (see Fig. 7). Over 20 years, their proportion increased from 1.9 to 5.0. Over this period, the HM varied with a distinct upward trend. In 2019, it amounted to 78 cases per 1 million population, which is 5.2 times higher than in 2001 (see Fig. 6). This is probably due to an increase in the survival rate of newborns with severe pathology.

Vascular lesions of the nervous system are extremely rare in children (see Fig. 7). Their proportion in the structure of neurosurgical pathology for which children were hospitalized was 2.8%. In 2001, the prevalence of this pathology was 5 cases per 1 million children. Within 17 years, this rate increased to 46 (9.2 times), and decreased in 2019–2020, reaching 2011 level in 2020 (26 cases) (see Fig. 6).

The frequency of acute spinal trauma in children has remained almost unchanged over 20 years (1.2–1.5%). Only an increase up to 2% was recorded in 2009–2010. In relation to HM for this pathology, the value of the indicator varied in different years with a slight tendency to double in general (see Fig. 6).

One of the indicators of surgical service efficiency is surgical activity - the ratio of the number of operated on and hospitalized patients (%). Despite the 20-year decrease in the number of operated patients, surgical activity increased from 28.3% in 2001 to 34.8% in 2020 (see Table 2, Fig. 8).

The main requirement for the development of any medical field, particularly pediatric neurosurgery, is the widespread implementation of modern diagnostic and treatment methods into practice. Accurate diagnosis, which significantly affects the thoroughness of patients selection for surgery, and constantly improving methods of surgical interventions, improve the treatment outcomes, in particular, reducing postoperative lethality. Thus, in the first 15 years of the studied period, postoperative lethality varied without a definite trend, whereas over the past 5 years, a twofold decrease in the indicator has been recorded. Even quarantine measures had a slight effect on postoperative lethality (see Fig. 8).

The structure of pediatric neurosurgical pathology has changed over the last 20 years. Acute cerebrocranial trauma was and still is the main pathology in the structure of neurosurgical interventions. However, the absolute number of children operated on with acute craniocerebral trauma decreased over time from 1954 to 1269 (by 35%), and its proportion of the total pathology decreased from 64.2% in 2001 to 40.4% in 2020 (Fig. 9). In our opinion, this trend is associated with a 45.3% decrease in the number of children in Ukraine. If the number of children remained unchanged (standardization by the number of children in 2001), the number of children operated on for craniocerebral trauma in 2020 would be 2,317, i.e.

18.6% more than in 2001, i.e. when the indicator was standardised, an increase in the number of cases of pediatric acute craniocerebral trauma was noted.

Advances in hydrocephalus treatment technologies in children have led to an increase in both the absolute number and the proportion of structure of neurosurgical pathology. Thus, in 2001, 281 children were operated on (9.2% of the total number of those operated on), in 2020 - 693 (22.8% of the total number of operations, an increase of 2.5 times) (see Fig. 9). The standardised figure for the number of children in 2020 is 1,265 people (i.e. 4.5 times more than in 2001).

Neuro-oncological diseases rank third in the structure of pediatric neurosurgical pathology, accounting for 8.4% in 2001 and 13.6% in 2020. The absolute number of patients operated on for neuro-oncological pathology in 2020 was 428, standardised by the number of pediatric population in 2001 - 781, which is 67.2% and 3 times higher than in 2001 (see Fig. 9). The main reason for this increase is unclear. It may be both a banal increase in oncological pathology of the nervous system in children and the development of diagnostic and treatment technologies leading to an increase in indications for surgical intervention.

The proportion of vascular diseases in the structure of neurosurgical interventions in children in 2001 was 0.5% (15 people), in 2020 it was 2.3% (71 people). Standardised to the number of children in 2001, the number of children operated on for neurovascular pathology in 2020 was 130, which is 8.7 times higher than in 2001. The small proportion of children operated on for neurovascular pathology is mainly due to the low morbidity of children with neurovascular pathology. Considering the significant increase of the standardised index, it is possible to state both the fact of the increase of such pathology as well as the improvement of diagnostic and surgical technologies in the neurovascular field.

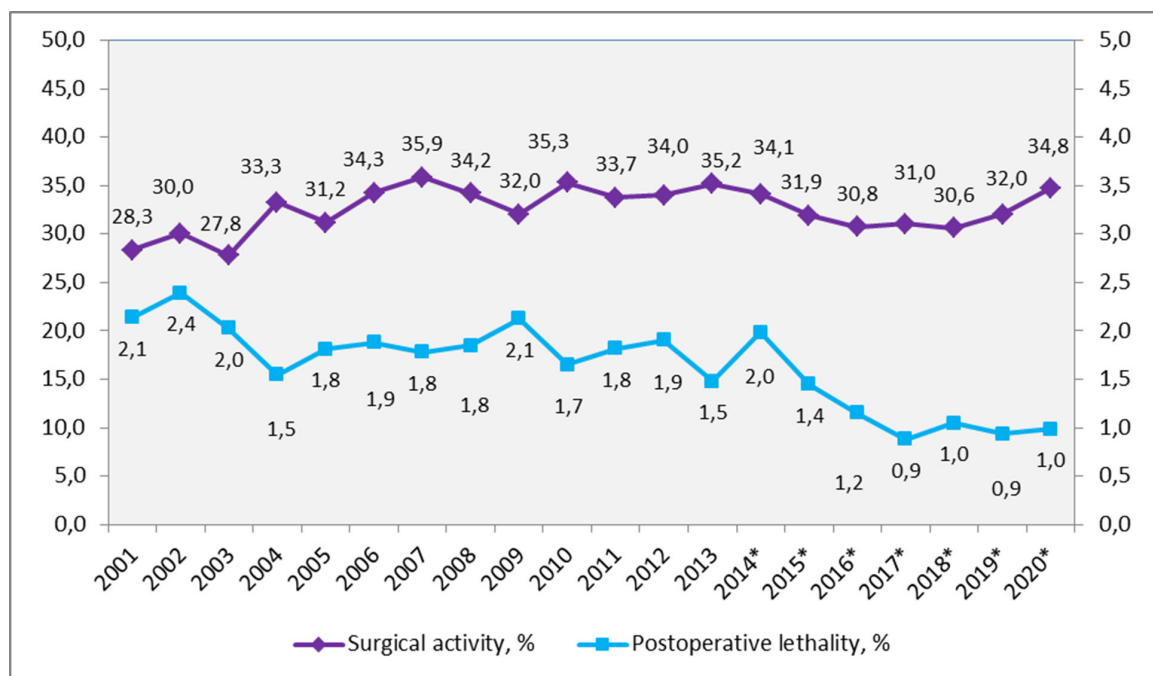


Fig. 8. Surgical activity and postoperative lethality by pediatric neurosurgical pathology

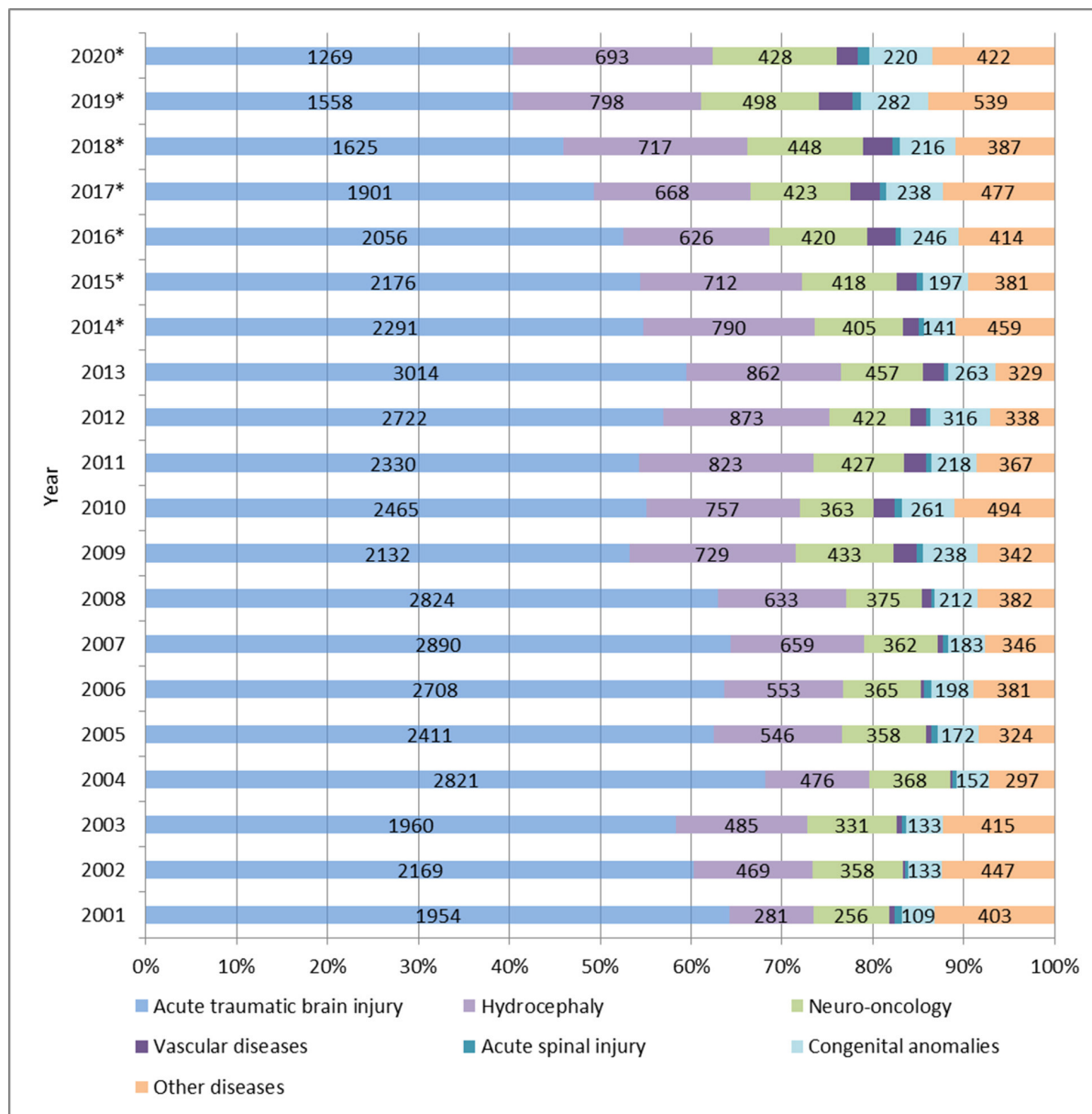


Fig. 9. Structure of neurosurgical pathology for which children were underwent surgery on

Another nosological form, which accounts for an insignificant part in the structure of neurosurgical pathology in children, is acute spinal injury. Over 20 years, the frequency of this pathology increased from 0.8 to 1.3. In 2001, 26 children were operated on, in 2020 – 41, the standardized value is 75. The increase is 1.6 times, the standardized number is almost 3 times.

In 2001, 109 children with congenital malformations of the nervous system were operated on (3.6% of all neurosurgical pathology), in 2021 there were already 220 (7%) of such patients (see Fig. 9), standardized by the number of children in 2001 – 402, so it is safe to say that the number of children with congenital malformations of the nervous system is increasing.

Conclusions

1. Ukraine is a country with high availability of pediatric neurosurgical care. There is no statistically significant difference between Ukraine and high-income

countries in the distribution of pediatric neurosurgical beds (p=0.9987).

2. For 20 years the availability of neurosurgical beds for child population has more than doubled, from 17 beds per 1 million children in 2001 to 38 in 2020.

3. The availability of pediatric neurosurgeons for the pediatric population has increased more than 3 times over the past 20 years and currently meets the standard of the Ministry of Health of Ukraine (7.7 per 1 million children).

4. Established in 2001–2013, the trend towards a significant increase in both absolute and relative rates of hospitalization and surgery for children with neurosurgical pathology in subsequent years due to the annexation of Crimea, military actions in Donbas and the COVID-19 pandemic changed to a decreasing trend.

5. The most common neurosurgical pathology in children is acute traumatic brain injury (according to 2019 data, 966 cases per 1 million child population

were hospitalized), followed by hydrocephalus (149 per 1 million child population), the third is neuro-oncological disease (110 per 1 million child population). One of the rare nosological forms is acute spinal trauma (19 cases per 1 million child population).

6. In general, over 20 years, only the absolute number of hospitalized children decreased by 15.8%, while the absolute number of operated on increased by 3.3%. The hospitalization rate per 1 million child population increased by 53.8%, the surgery rate - by 88.7%.

7. The use of methods of diagnosis and surgical treatment of pediatric neurosurgical pathology, which have been improved over the past 20 years, contributed to an increase in surgical activity by 6.5% (from 28.3% in 2001 to 34.8% in 2020) and a more than two-fold decrease in postoperative lethality (from 2.1% in 2001 to 1.0% in 2020).

Disclosure

Conflict of interest

The authors declare no conflicts of interest and no personal financial interest in the preparation of this article.

Ethical guidelines

This article contains no studies involving humans or animals.

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