

The impact of the COVID-19 pandemic on the number of brain tumor surgeries in Poland: A national database study

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Abstract

Background. The coronavirus disease (COVID-19) pandemic has greatly affected the treatment of most medical conditions. In particular, the treatment of seriously ill patients had to be adjusted due to the limited availability of in-hospital procedures.

Objectives. The aim of this study was to evaluate the effects of COVID-19-related changes on neuro-oncological surgeries in the Polish medical system.

Materials and methods. Data from the period of 2010–2020 were collected from National Health Insurance database for 2 diagnosis-related groups: A11 (complex intracranial procedures) and A12 (large intracranial procedures). The total number of procedures and diagnoses per year, trend changes and changes in procedures grouped by medical type were analyzed, including resections/biopsies, malignant/stable (nonmalignant) lesions, elective/acute procedures, and length of stay.

Results. Mean yearly numbers of 7177 (standard deviation (SD) = 760) procedures and 5934 (SD = 1185) diagnoses were recorded. Both numbers were growing up to 9.1% per year until 2018. From 2018, a 3.1% decrease in the number of procedures was observed, with a significantly larger decrease of 10.5% observed in 2020 ($p < 0.001$). The number of diagnoses decreased in 2019 by 2.7%, and by 9.2% in 2020 ($p = 0.706$), with a statistically significant change in the annual growth rate ($p = 0.044$). The number of resections decreased by 11.5% in 2020 ($p = 0.204$), with a significant change in the annual growth rate ($p < 0.001$). The number of biopsies decreased by 2.5% in 2020 ($p = 0.018$), with the annual decrement in 2019/2020 also being significant ($p = 0.004$). Decreases were observed in 2019 and 2020 for the number of malignant (0.5% and 6.3%, respectively) and nonmalignant (5.4% and 12.9%, respectively) tumors ($p = 0.233$ and $p = 0.682$ for absolute values, and $p = 0.008$ and $p = 0.004$ for the annual growth rates, respectively). The number of acute procedures in 2020 further decreased by 9.8% from 5.5% decrease in 2019 ($p = 0.004$), and the number of elective procedures decreased by 11.8% ($p = 0.009$). The annual growth rates for both acute and elective procedures were statistically significant ($p < 0.001$ and $p < 0.001$).

Conclusions. The decrease in the number of neuro-oncological surgeries appeared to be much lower than the 20% decrease observed for general oncological surgeries in Poland during the COVID-19 pandemic. This seems to have resulted from postponing the treatment of less critical cases (i.e., nonmalignant and elective) and focusing on the treatment of the most precarious patients.

Key words: Poland, neuro-oncology, brain tumor, COVID-19, trend change

Background

During the coronavirus disease (COVID-19) pandemic, the medical environment for the treatment of many conditions has changed. The new disease has presented itself quickly, overwhelming parts of the national healthcare system and resulting in a great number of severely ill patients. A limited number of treatment options for COVID-19 and the necessity to stop the spread of the virus have increased the burden. The treatments for medical conditions other than COVID-19 have had to be adjusted due to the limited availability of in-hospital procedures. Various treatments have been restricted due to the transformation of hospitals into infectious departments, the loss of healthcare practitioners during quarantine, the need to develop new procedures to treat COVID-19 patients, and even the availability of personal protective equipment.

This novel situation has also affected brain tumor surgery and has forced adjustments to previous treatment protocols.^{1–4} One of the major changes has been a decrease in the availability of intensive care units (ICUs), which are necessary for the early postoperative period.⁵ This was primarily due to a large scale increase in the number of ICU patients suffering from respiratory failure secondary to COVID-19 pneumonia.^{6–8} A second important factor was an attempt to cut/stop viral spread by implementing new procedures. These protocols aimed to decrease the contact between healthcare practitioners and patients, and to limit the number of physicians involved in a single procedure.³ These limitations have also stressed outpatient systems and basic healthcare, and decreased the number of medical examinations, resulting in an increase in the number of teleconsultations. Additionally, delays in diagnostic workups were observed.^{9–11}

Objectives

The aim of this paper is to evaluate the impact of COVID-19-related changes in the Polish medical healthcare system on brain neuro-oncological surgeries. To this end, data were collected from the National Health Insurance database. The total number of procedures and diagnoses per year, changes in trends in the following years, and changes in the number of procedures grouped by their medical type were analyzed.

Materials and methods

Data on the number of brain tumor surgeries carried out in Poland were collected from the Polish National Health Fund (NHF; in Polish, Narodowy Fundusz Zdrowia (NFZ)) database. The NHF is a governmental medical insurance agency that is the sole public funding source for medical treatments in Poland. The data are publicly reported each

year and are grouped according to the diagnosis-related group (DRG) system. The basic details reported for each DRG include the number of corresponding International Classification of Diseases (ICD)-9 procedures and ICD-10 diagnoses (both limited to about 50 of the most frequently reported), related length of stay (LOS), and the percentages in relation to the total numbers. Demographic data are provided for the whole DRG. Despite these limitations, it is the most representative public data source on the Polish public medical system. The NHF database is published according to relevant legal acts, and is anonymized and free to use. Therefore, ethical committee approval was not necessary for this study.

Brain tumor surgery is reported under 2 DRG procedures: A11 (complex intracranial procedures) and A12 (large intracranial procedures). The coded ICD-10 diagnosis represents the most significant medical finding reported during hospitalization, which was the target of treatment. The simultaneously coded ICD-9 procedure represents the first, most representative procedure carried out during the treatment of the patient, thus indicating the objective of hospitalization. Data on ICD-9 procedures are presented for the entire analyzed period and data on ICD-10 diagnoses are presented since 2014. For the analysis, data on ICD-9 procedures and ICD-10 diagnoses associated with neuro-oncology were collected from each DRG with the corresponding LOS. Later, the ICD-9 procedures and ICD-10 diagnoses were divided into subgroups focusing on the general way in which they are carried out. These subgroups included:

- types of ICD-9 procedures: resection (01.512, 01.595, 01.599, 04.011, 04.012, 07.62, 07.65) and biopsy (01.131, 01.132, 01.14);
- types of ICD-10 diagnoses: mostly malignant (C71, C71.0–C71.6, C71.9, C79.3), stable (nonmalignant) lesions (D32.0, D33.0, D33.1, D33.3, D35.2).

The ICD-9 procedures were additionally divided into typically highly elective treatments (e.g., cerebellopontine angle tumor removal (01.512, 04.011, 04.012, 07.62, 07.65)) and those more typically performed in a shorter time after diagnosis, such as high-grade glioma (HGG) or metastasis – acute (01.131, 01.132, 01.14, 01.595, 01.599) (Table 1).

Statistical analyses

The frequencies of each of the analyzed variables in 2020 were compared with the frequencies reported in the preceding years. Moreover, the annual growth rates were calculated (the difference between the value for a given variable observed in a given year compared to its value from the previous year), and the increase/decrease in the observed values for 2019–2020 were compared to the annual growth rates from the preceding years.

The data from the years preceding the COVID-19 pandemic were examined for normal distributions using the Shapiro–Wilk test, which has the highest statistical power for small sample sizes. After verifying the assumptions,

Table 1. Codes in International Classification of Diseases (ICD) – ICD-9 and ICD-10

ICD-9				ICD-10		
Code	description	typical aim of procedure	typical performance	code	description	lesion typically
01.512	excision of brain dura	resection	elective	C71	malignant brain tumor	malignant
01.595	excision of cerebellar tumor	resection	acute	C71.0–C71.6	malignant brain tumor	malignant
01.599	excision of brain tumor – other	resection	acute	C71.9	as above in following brain anatomic locations	malignant
04.011	acoustic neuroma excision	resection	elective	C79.3	metastatic brain and dural tumor	malignant
04.012	acoustic neuroma excision with craniotomy	resection	elective	D32.0	nonmalignant dural brain tumor	nonmalignant
07.62	partial transsphenoidal hypophysectomy	resection	elective	D33.0	nonmalignant tumor (brain, supratentorial)	nonmalignant
07.65	complete transsphenoidal hypophysectomy	resection	elective	D33.1	nonmalignant tumor (brain, subtentorial)	nonmalignant
01.131	transcutaneous brain biopsy with trepanation	biopsy	acute	D33.3	nonmalignant tumor (cranial nerves)	nonmalignant
01.132	transcutaneous stereotactic brain biopsy	biopsy	acute	D35.2	nonmalignant tumor (hypophysis)	nonmalignant
01.14	open brain biopsy	biopsy	acute			

a two-tailed Student's t-test was used to test the null hypothesis of equality of the mean value for the observations from previous years with the value observed in the given year. The alternative hypothesis was that these values were not equal. A value of $p < 0.05$ was considered statistically significant. The results are presented in Table 2.

In addition, the number of malignant tumors reported in the 1st year of observation and the number of elective procedures conducted in the 2nd year of observation were considered as outliers, and these were removed from the analyses. Later in the article, the possibility

of the influence of the method of supplementing data in the collective database at the beginning of the national registry's operation is discussed, taking into account the observation values from subsequent years and the fact that the number of malignant tumors reported in 2014 was clearly underestimated (Fig. 1). The number of elective surgeries in the 2nd year of follow-up was considered an outlier based on a scatterplot (Fig. 2). On the basis of similar criteria, the number of diagnoses in the 1st recorded year (2014) and the number of resections in the 2nd year of observation (2011) could also

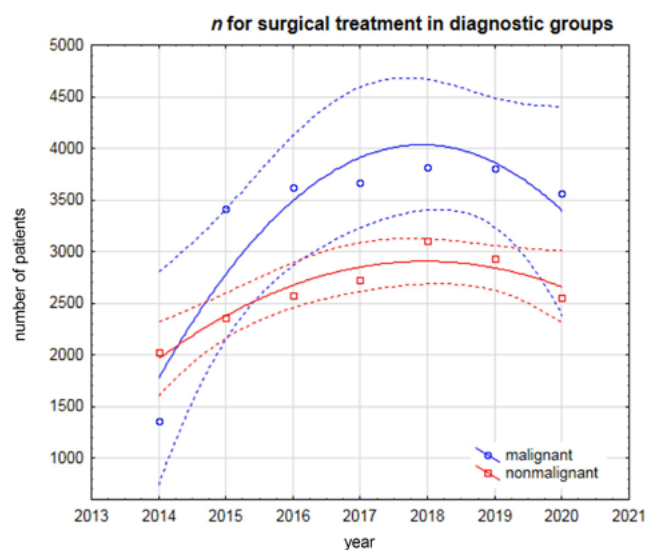


Fig. 1. Number of neuro-oncosurgical treatment in the diagnostic group. The dashed lines show the 95% confidence interval (95% CI) for the polynomial trends fitted to the data with the use of least squares method (solid line): $y = -6.0042 \times 108 + 5.9509 \times 105x - 147.4524x^2$ for malignant, and $y = -2.4457 \times 108 + 2.42 \times 105x - 60.0595x^2$ for nonmalignant tumors (x – year)

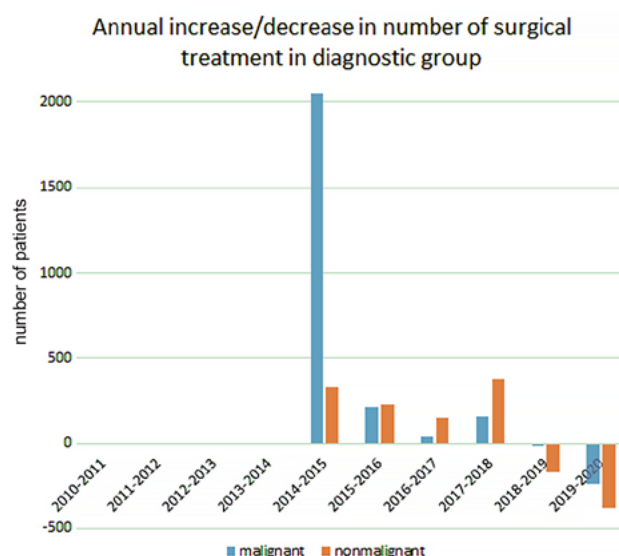


Fig. 2. The annual growth rates in the diagnostic group. The decrease in the number of operations is particularly visible for the resection of nonmalignant tumors in 2020. The analyzed database does not contain information on the diagnoses before 2014, due to Polish National Health Fund (NHF; in Polish, Narodowy Fundusz Zdrowia (NFZ)) database limits

Table 2. Results of statistical analyses for variables related to neurosurgical treatment of brain tumors.

Examined variable		Statistical test		Interpretation
		Shapiro–Wilk test	Student's t-test	
Procedures	number per year	W = 8655; p = 0.089	t = 1.195; df = 9; p = 0.263	The number of procedures in 2020 does not differ from the mean from previous years, but their decrease between 2019 and 2020 differs from the mean growth from previous years.
	year-on-year growth	W = 0.961; p = 0.809	t = 8.481; df = 8; p < 0.001	
Diagnoses	number per year	W = 0.781; p = 0.059	t = -0.399; df = 5; p = 0.706	The number of diagnoses in 2020 does not differ from the mean from previous years, but their decrease between 2019 and 2020 differs from the mean growth from previous years.
	year-on-year growth	W = 0.807; p = 0.092	t = 2.906; df = 4; p = 0.044	
Resections	number per year	W = 0.865; p = 0.087	t = 1.368; df = 9; p = 0.204	The number of resections in 2020 does not differ from the mean from previous years, but their decrease between 2019 and 2020 differs from the mean growth from previous years.
	year-on-year growth	W = 0.971; p = 0.906	t = 5.649; df = 8; p < 0.001	
Biopsies	number per year	W = 0.894; p = 0.187	t = -2.890; df = 9; p = 0.018	Both the number of biopsies in 2020 and their decrease between 2019 and 2020 differ from their mean values from previous years.
	year-on-year growth	W = 0.920; p = 0.395	t = 3.982; df = 8; p = 0.004	
Malignant tumors	number per year	W = 0.909; p = 0.463	t = 1.403; df = 4; p = 0.233	The number of diagnoses of malignant tumors in 2020 does not differ from the mean from previous years, but their decrease between 2019 and 2020 differs from the mean growth from previous years.
	year-on-year growth	W = 0.955; p = 0.747	t = 6.464; df = 3; p = 0.008	
Nonmalignant tumors	number per year	W = 0.981; p = 0.9575	t = 0.434; df = 5; p = 0.682	The number of diagnoses of nonmalignant tumors in 2020 does not differ from the mean from previous years, but their decrease between 2019 and 2020 differs from the mean growth from previous years.
	year-on-year growth	W = 0.887; p = 0.344	t = 5.865; df = 4; p = 0.004	
Elective	number per year	W = 0.797; p = 0.056	t = 7.994; df = 5; p < 0.001	Both the number of elective surgeries in 2020 and their decrease between 2019 and 2020 differ from their mean values from previous years.
	year-on-year growth	W = 0.920; p = 0.391	t = 3.414; df = 8; p = 0.009	
Acute	number per year	W = 0.860; p = 0.075	t = 3.862; df = 9; p = 0.004	Both the number of acute surgeries in 2020 and their decrease between 2019 and 2020 differ from their mean values from previous years.
	year-on-year growth	W = 0.970; p = 0.892	t = 7.151; df = 8; p < 0.001	

For each variable, their absolute numbers in subsequent years and annual increments were analyzed, and the observation from the period of change caused by the coronavirus disease (COVID-19) pandemic (2020 and the decrease in 2019–2020) was compared to the mean values from previous years. The table presents the results of the Shapiro–Wilk test of normality for observations from previous years (values of the test statistic W and the p-value), which is a prerequisite for the correct application of the Student's t-test, and the results of the Student's t-test (values of the test statistic (t), the number of degrees of freedom (df) and the p-value). Statistically significant p-values at the significance level of 0.05 are in bold.

be considered outliers. However, their elimination did not change the statistical significance for the examined changes in the year of the pandemic; hence, the results are presented without their elimination.

Changes in the values of the analyzed variables over time are presented graphically in plots in the Results section. Scatterplots were used for the absolute values of the observed quantities, presenting their changes over time with the fitting of an illustrative nonlinear (polynomial) trend. For the plotting, it was assumed that a second-degree polynomial would be fitted to the data, and the method of least squares was applied for approximation. Bar graphs were used to present the annual differences.

Results

In the whole Results section, the following symbols are used for statistical measures: M – mean, SD – standard deviation, p – p-value, W – the Shapiro–Wilk test statistic, t – the Student's t-test statistic, df – degrees of freedom. All p-values are presented with a test name.

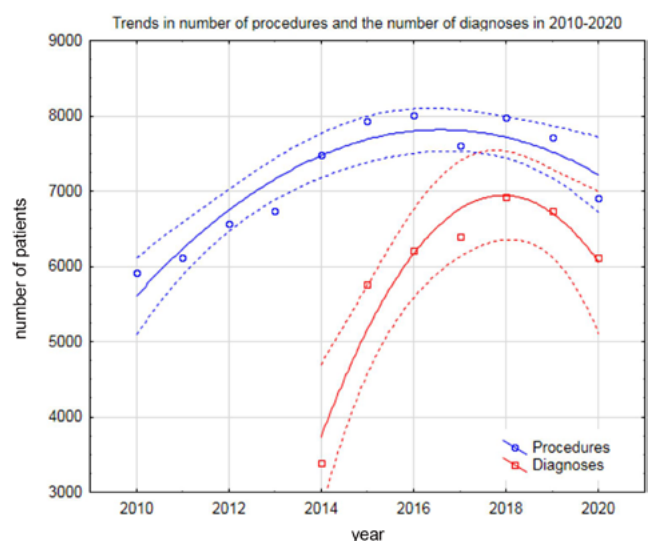


Fig. 3. Changes in the number of neuro-oncological surgeries performed and the number of diagnoses made in the years 2010–2020. The dashed lines show the 95% confidence interval (95% CI) for the polynomial trends fitted to the data with the use of least squares method (solid line): $y = -2074 \times 108 + 2.057 \times 105x - 51.0023x^2$ for procedures, and $y = -8.4499 \times 108 + 8.3749 \times 105x - 207.5119x^2$ for diagnoses (x – year)

Table 3. Number of patients per year in relation to ICD-9

Code	Procedure	2010		2011		2012		2013		2014		2015		2016		2017		2018		2019		2020		
		n per year	median LOS	n per year	median LOS	n per year	median LOS	n per year	median LOS	n per year	median LOS	n per year	median LOS	n per year	median LOS	n per year	median LOS	n per year	median LOS	n per year	median LOS	n per year		
ICD-9	01.131	percutaneous brain biopsy with trepanation	91	7.0	128	7.0	146	8.0	155	7.0	211	7.0	215	9.0	231	7.0	205	7.0	190	6.0	231	6.0	209	6.0
	01.132	stereotactic brain biopsy	323	5.0	330	4.0	380	4.0	380	4.0	416	4.0	462	4.0	470	4.0	450	4.0	491	4.0	494	3.0	464	3.0
	01.14	open brain biopsy	79	9.0	75	9.0	93	9.0	91	10.0	93	10.0	108	11.0	125	8.0	116	10.0	120	9.0	111	8.0	142	7.0
	01.512	dura matter removal	628	10.0	773	10.0	1200	10.0	1293	10.0	1755	10.0	1755	10.0	1891	9.0	1756	9.0	2041	8.0	2102	8.0	1844	8.0
	01.595	cerebellar tumor excision	324	14.0	312	14.0	298	14.0	275	13.0	272	13.0	293	13.0	260	12.0	263	11.0	247	11.0	163	11.0	159	10.0
	01.599	other brain tumor excision	3594	12.0	3531	11.5	3527	12.0	3565	12.0	3675	10.5	4044	10.5	4064	11.0	3917	10.5	4078	10.0	3841	10.0	3390	9.0
	04.011	acoustic schwannoma excision	126	16.0	128	16.0	133	15.0	121	16.0	116	13.0	116	13.0	106	13.0	-	-	-	-	-	-	-	-
	04.012	acoustic schwannoma excision with craniotomy	170	13.0	155	11.0	151	12.0	144	11.0	105	11.0	105	11.0	106	13.0	139	11.0	138	10.0	124	12.0	106	11.0
	07.62	transsphenoidal partial hypophysectomy	587	8.0	684	8.0	644	8.0	711	8.0	741	7.0	741	7.0	749	7.0	755	7.0	667	7.0	655	7.0	590	6.0
	07.65	transsphenoidal total hypophysectomy	-	-	-	-	-	-	57	7.0	92	8.0	92	8.0	-	-	-	-	-	-	-	-	-	-
Total		5922	10.4	6116	10.1	6572	10.2	6735	9.8	7476	9.4	7931	9.7	8002	9.3	7601	8.7	7972	8.1	7721	8.1	6904	7.5	

ICD – International Classification of Diseases; LOS – length of stay.

For groups A11 and A12 of the DRG related to brain tumor surgery, mean numbers of 7177 (SD = 760) procedures and 5934 (SD = 1185) diagnoses per year were observed (Table 3,4). During the whole analyzed period, a marked diversity in the number of cases per year can be seen, with a wide spread in the numbers. These changes were visualized using a scatterplot with a nonlinear trend (Fig. 3).

The annual growth rates in diagnoses and procedures are shown in Fig. 4. The disproportionally large increase in the number of diagnoses between the years 2014 and 2015 was caused most probably by a partial failure in reporting to the NFZ, due to the implementation of a new reporting tool. Until 2018, the total number of oncological procedures and diagnoses grew at a rate of 3.2–9.1% per year. After 2018, a decrease in percentages was observed compared to the previous year. The decrease of 3.1% in the number of procedures conducted in 2019 intensified to 10.5% in 2020, with a further down-bending of the curve representing the number of cases. The whole previous period was statistically insignificant for both procedures ($t = 1.195$, $df = 9$, $p = 0.263$) and diagnoses (Student's t -test, $t = -0.399$, $df = 5$, $p = 0.706$). These changes in time are shown in Fig. 3. The lack of differences is in large part caused by a high variability in the observations in individual years. However, when comparing the annual growth rates from 2020 to previous periods (Fig. 4), the decreases in the number of both procedures and diagnoses were significant (Student's t -test, $t = 8.481$, $df = 8$, $p < 0.001$, and $t = 2.906$, $df = 4$, $p = 0.044$, respectively).

The length of hospitalization related to all procedures steadily decreased during the whole analyzed period (Fig. 5). While there were some increases in LOS in the years 2015 and 2019, the overall trend decreased monotonically. When analyzing the year-to-year changes, the LOS decrease started with 1% per year, with a general rate of 6% per year. This process accelerated to 7% in 2020.

For procedures subdivided into resection or biopsy, the mean numbers per year were 6404 (SD = 767) and 711 (SD = 123), respectively. The number of resections initially grew between 2010 and 2018 at a rate of 2–9.5% per year. It started to decrease in 2018 by 3.9%, with a marked decrease in 2020 by 11.5% (Fig. 6). Although no statistical significance (Student's t -test, $t = 1.368$ $df = 9$, $p = 0.204$) was found for the absolute values, the relative

Table 4. Number of patients per year in relation to ICD-10 codes

Code	Diagnosis	2010		2011		2012		2013		2014		2015		2016		2017		2018		2019		2020	
		n per year	median LOS	n per year	median LOS	n per year	median LOS	n per year	median LOS	n per year	median LOS	n per year	n per year	median LOS	n per year	median LOS	n per year	n per year	median LOS	n per year	n per year	median LOS	
C71	malignant brain tumor	–	–	–	–	–	–	–	–	–	–	72	6.0	74	3.0	86	6.0	79	3.0	–	–	–	
C71.0	malignant tumor (except for lobes and ventricles)	–	–	–	–	–	–	–	–	86	13.0	86	13.0	83	12.0	135	12.0	207	10.0	202	9.0	164	
C71.1	malignant tumor (frontal lobe)	–	–	–	–	–	–	–	–	340	11.0	891	10.5	854	8.5	932	9.5	886	9.5	892	8.5	932	
C71.2	malignant tumor (temporal lobe)	–	–	–	–	–	–	–	–	284	10.0	701	10.0	702	9.0	680	9.5	735	9.0	683	8.5	638	
C71.3	malignant tumor (parietal lobe)	–	–	–	–	–	–	–	–	238	10.0	575	10.0	581	10.0	544	10.0	564	9.0	575	9.0	468	
C71.4	malignant tumor (occipital lobe)	–	–	–	–	–	–	–	–	–	–	107	11.0	192	9.0	198	9.0	213	10.0	240	8.5	202	
C71.6	malignant tumor (cerebellum)	–	–	–	–	–	–	–	–	101	13.0	277	12.0	297	12.0	277	11.5	313	11.0	265	10.0	236	
C71.9	malignant tumor (brain, unspecified)	–	–	–	–	–	–	–	–	137	8.0	296	8.0	313	8.0	329	8.0	285	8.0	409	8.5	343	
C79.3	secondary malignant brain and dura tumor	–	–	–	–	–	–	–	–	177	9.0	408	9.0	530	9.5	487	10.0	540	9.5	538	8.5	580	
D32.0	nonmalignant dura matter tumor	–	–	–	–	–	–	–	–	550	10.0	653	11.0	779	10.5	827	10.5	831	10.0	915	9.0	773	
D33.0	nonmalignant tumor (brain, supratentorial)	–	–	–	–	–	–	–	–	528	12.0	750	11.5	720	11.0	795	10.5	1128	10.0	922	8.5	847	
D33.1	nonmalignant tumor (brain, infratentorial)	–	–	–	–	–	–	–	–	184	13.0	184	13.0	244	12.0	284	12.0	303	12.5	258	12.0	246	
D33.3	nonmalignant tumor (cranial nerves)	–	–	–	–	–	–	–	–	768	9.5	119	12.0	139	12.0	140	11.0	175	10.0	144	11.0	111	
D35.2	nonmalignant tumor (hypophysis)	–	–	–	–	–	–	–	–	–	–	649	7.0	697	7.0	682	7.0	665	7.0	694	7.0	575	
Total										3393	10.8	5768	10.6	6205	10.0	6396	10.0	6924	9.7	6737	9.1	6115	
																						8.5	

ICD – International Classification of Diseases; LOS – length of stay.

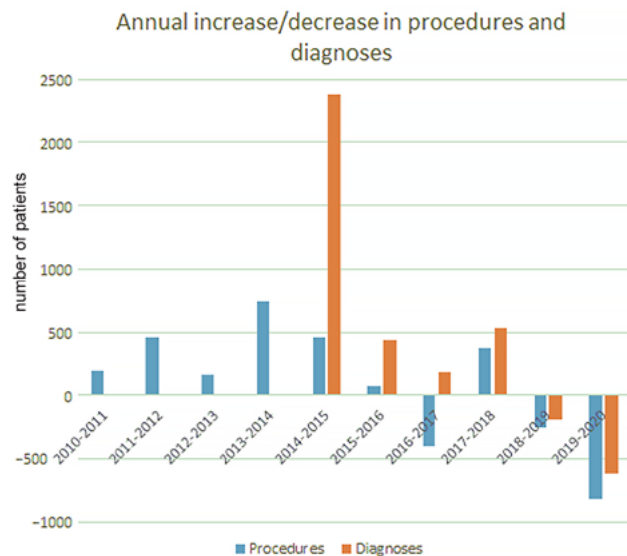


Fig. 4. The annual growth rates in diagnoses and procedures. In the years 2018–2020, there is a clear decrease in both values. The analyzed database does not contain information on the diagnoses before 2015, due to Polish National Health Fund (NHF; in Polish, Narodowy Fundusz Zdrowia (NFZ)) database limits

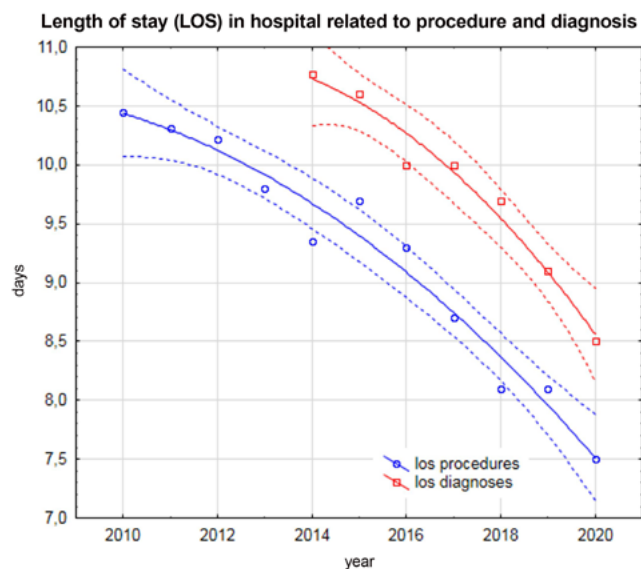


Fig. 5. Changes in the length of stay (LOS) in hospital for procedures and diagnoses in the years 2010–2020. The dashed lines show the 95% confidence interval (95% CI) for the polynomial trends fitted to the data with the use of least squares method (solid line): $y = -68162.4098 + 67.957x - 0.0169x^2$ for procedures, and $y = -1.3179 \times 105 + 131.0492x - 0.0326x^2$ for diagnoses (x – year)

decrease in the number of resections in 2020 compared to the previous years was significant (Student's t-test, $t = 5.649$, $df = 8$, $p < 0.001$). The total number of biopsies in 2020 also significantly decreased compared to previous years (Student's t-test, $t = -2.890$, $df = 9$, $p = 0.018$). The increase in biopsies seemed to be more stable over the years than the increase in resections, with an average of 8% and a minimal decrease of 2.5% in 2020, which was statistically significant (Student's t-test, $t = 3.992$, $df = 9$, $p = 0.004$). These trends are shown in Fig. 7.

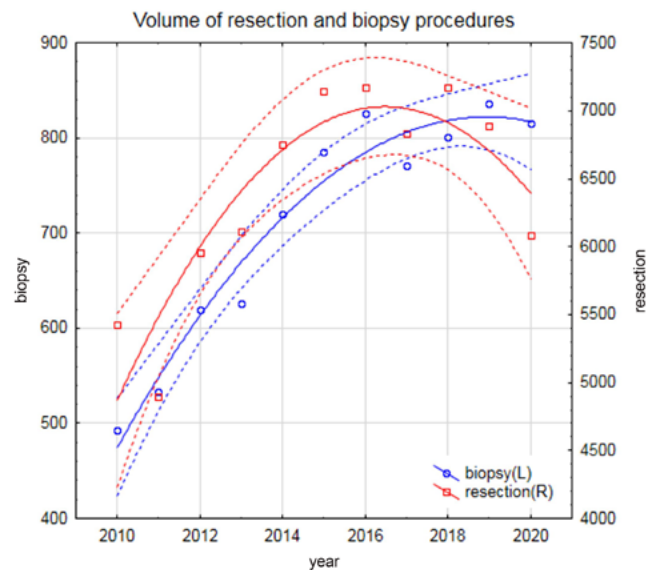


Fig. 6. Changes in the number of resection and biopsy procedures. The dashed lines show the 95% confidence interval (95% CI) for the polynomial trends fitted to the data with the use of least squares method (solid line): $y = -1.7373 \times 107 + 17201.003x - 4.2576x^2$ for biopsies, and $y = -1.5773 \times 108 + 1.563 \times 105x - 38.7197x^2$ for resections (x – year)

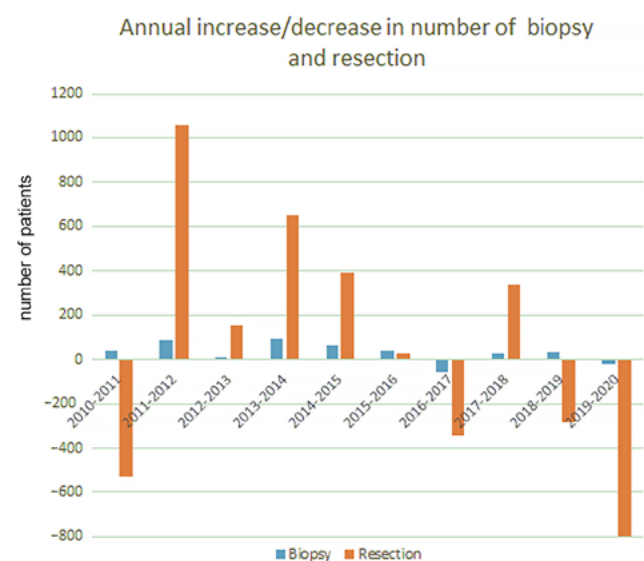


Fig. 7. The annual growth rates for resection and biopsy procedures. There is a relatively greater decrease in the number of resections than in the number of biopsies as a result of the coronavirus disease (COVID-19) pandemic

When looking at the diagnosis and comparing procedures related mostly to malignant ($M = 3323$, $SD = 875$) or stable (nonmalignant) lesions ($M = 2611$, $SD = 357$), both were increasing at the beginning of the analyzed period. A decrease started in 2019, followed in 2020 by increases of 0.5% and 6.3% for malignant, and 5.4% and 12.9% for nonmalignant lesions, respectively. The annual growth rates are shown in Fig. 2, and their changes over time are outlined in Fig. 1. The number of diagnoses for both subgroups in relation to the average numbers in previous years

did not differ significantly (Student's *t*-test, $t = 1.403$, $df = 4$, $p = 0.233$ for malignant, and $t = 0.434$, $df = 5$, $p = 0.682$ for nonmalignant tumors). However, the decrease in diagnoses for both malignant and nonmalignant tumors between 2019 and 2020 was statistically significantly different from their mean growth in the previous years (Student's *t*-test, $t = 6.464$, $df = 3$, $p = 0.008$, and $t = 5.865$, $df = 4$, $p = 0.004$, respectively). As can be seen in Fig. 1, there is an outlier value for the reported cases in the first year of data collection (2015), which may have impacted the results. Therefore, this observation was excluded from the analysis.

The procedures divided by typical performance showed fewer highly elective cases ($M = 2400$, $SD = 611$) than

those performed in a shorter time since diagnosis (acute) ($M = 4702$, $SD = 335$; Fig. 8). The absolute number of acute procedures in 2020 was significantly higher (Student's *t*-test, $t = 3.862$, $df = 9$, $p = 0.004$) compared to previous years and decreased by 5.5% in 2019, and by 9.8% in 2020. Also, the decrease in the number of acute surgeries between 2019 and 2020 differs from the mean value reported in previous years (Student's *t*-test, $t = 7.151$, $df = 8$, $p < 0.001$).

Elective procedures showed a decrease in 2020 at a rate of 11.8%, which was statistically significant (Student's *t*-test, $t = 3.414$, $df = 8$, $p = 0.009$). The decrease between 2019 and 2020 in comparison to the mean value from previous years was also significant (Student's *t*-test, $t = 7.994$, $df = 5$, $p < 0.001$). This time series is presented in Fig. 9.

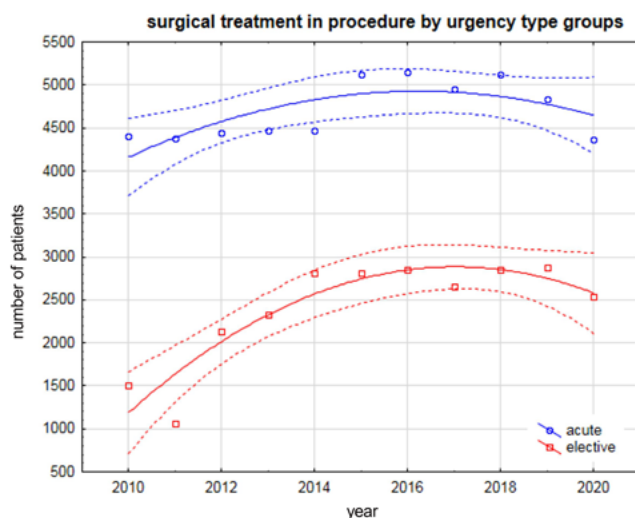


Fig. 8. Number of acute and elective procedures in the years 2010–2020. The dashed lines show the 95% confidence interval (95% CI) for the polynomial trends fitted to the data with the use of least squares method (solid line): $y = -8.018 \times 10^7 + 79539.8788x - 19.7249x^2$ for acute, and $y = -1.3979 \times 10^8 + 1.3862 \times 10^5x - 34.3613x^2$ for elective procedures (x – year)

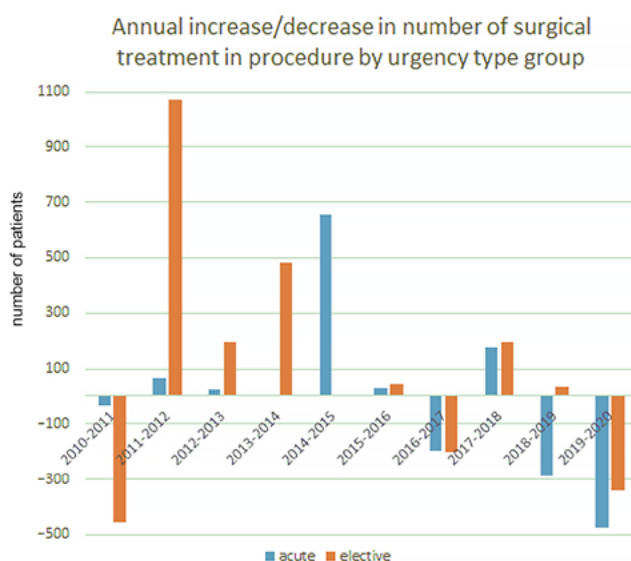


Fig. 9. The annual growth rates for acute and elective procedures. The decrease in the absolute number of procedures as a result of the coronavirus disease (COVID-19) pandemic is visible

Discussion

The COVID-19 pandemic has had a significant impact on the human community. In Poland, the first patient was diagnosed in March 2020. With growing numbers of COVID-19 patients, preventive actions were initiated by the government, which were predominantly focused on social distancing. The growing knowledge of the biological character of COVID-19, its routes of transmission, medical treatment, and, most importantly, progress in vaccination has lowered the need for social distancing. Nevertheless, social distancing and polymerase chain reaction (PCR) testing are still the main methods for disease prevention, and these strategies influence many stages of medical treatment.

One group of patients that requires urgent treatment is those with oncological diagnoses. In the case of malignant tumors, a delay in treatment is the main cause of a worsening prognosis.¹² Indeed, a 4-week delay impacts morbidity and mortality for all treatment methods, including surgery, radiotherapy and systemic treatment (6–8%, 9% and 13%, respectively).¹³ Before the COVID-19 pandemic, there were 2 main causes of delayed treatment. The most common patient-related reason was financial (28%), followed by problems with travel (living far away from treatment facilities (12.7%), dependency on help of others (9%)), and ignoring the disease (16%).¹⁰ On the medical side, the delay was found to be significant if the patient was initially diagnosed outside of a large specialist center.¹⁰ The burden induced by these factors has increased during the pandemic.¹⁴ Changes in the number of surgeries and oncological therapies, rescheduling, and delays in outpatient treatment appear to be a global problem. These issues have affected most medical centers and their supply chains, including personnel availability (up to 79%).¹¹ The impact of COVID-19-related healthcare system changes on oncological patients was not uniform. Multiple factors (e.g., age, comorbidities, type of treatment, etc.) played a role in the final influence of COVID-19 restrictions on oncological treatments. Depending on the type of diagnosis, some patient

groups showed no changes in survival, and new solutions, such as telemedicine in the case of breast cancer outpatient treatment, were applied with very good results.^{9,15–18}

A special report by the Polish Oncological National Board focused on the influence of COVID-19 did not detect a long-term significant change in the general availability of treatment for oncological patients in Poland during the pandemic.⁹ The problems that emerged during the first few months of the pandemic have diminished. The most profound impact on oncology was observed during spring of 2020, when the first restrictions were put into place. During this period, the availability of ambulatory diagnostics was reduced and some procedures were completely suspended. Telemedicine was advocated as the primary method for contacting a physician.¹⁸ During the 2nd part of the year, the situation improved. However, many oncological patients were afraid of leaving their homes as these patients tend to be at higher risk for infection. The COVID-19 pandemic and the associated restrictions resulted in a decrease in new tumor detection by 10–20% in 2020, depending on the tumor type. Nevertheless, in the current study, no significant differences were observed in the number of chemo- and radiotherapy procedures in comparison to the previous period, except for the early spring. These results are in contrast to surgical treatment, which decreased by up to 20%. One of the reasons for this latter outcome is the fact that a large number of oncological surgical treatments in Poland are conducted at large multidisciplinary hospitals, many of which were transformed into infectious disease centers. Thus, chemo- and radiotherapy, mostly carried out at dedicated oncological centers, were not affected in the same way. It is expected by the board that the number of new oncological diagnoses may show a compensatory increase after normalization of the pandemic situation. However, initial data from 2021 do not support this hypothesis, with the numbers of diagnosed and treated cases comparable to those observed in 2019.⁹

In 2020, the general decrease in the number of NFZ-reported onco-neurosurgical procedures (10.5% decrease) was lower than the decrease in the number of oncological surgeries in general (20% decrease).⁹ The National Oncology Boards reported that the 10.5% decrease in neuro-oncology surgeries is comparable to other countries.¹⁹ This change in practice was present worldwide, with a reduction in neuro-oncological surgery reported to be up to 50% in some situations, due to a focus on COVID-19-negative cases or even only emergency cases for a period of time.²⁰ According to our observations, the total mean number of procedures and diagnoses in Poland in 2020 did not change compared to previous years. However, when looking at the trends, there was a marked decrease in general procedures, acute and elective treatments, and nonmalignant diagnoses. However, the trend remained stable for malignant diagnoses, which suggests that, in the Polish medical system, stable treatment and diagnostic plans were provided to oncological patients.

Patients already going through diagnostic procedures were allocated to treatment, which is why the mean number may have remained stable. For comparison, a UK study showed a change in treatment programs up to 10.7% for neuro-oncological patients, mostly due to stoppages in surgery or patient referrals for the best supportive care. The major parameter affecting the decision process was a poor prognosis. Treatment of low-grade lesions could be planned after the acute stage of the pandemic. The scale of changes in treatment plans decreased after the initial months of the pandemic.^{19,21}

In addition, our observations showed a marked decrease in the general trends in the number of patients and subgroups. These numbers most probably represent new diagnoses in patients who experienced an extended time to diagnosis and start of treatment. This extension, in many cases, was caused by the limited availability of emergency procedures due to the lockdown, decreased effectiveness of operating rooms (ORs) and decreased availability of imaging diagnostics. Neurosurgical centers have reported a decrease in the number of oncological patients due in part to treatment plan delays, but no change in outcome has been observed.^{18,22} The decrease in the number of neuro-oncological procedures was partially related to limited access to ICUs, which shifted to treating COVID-19 patients.^{5,6} Interestingly, Azab and Azzam reported that the rate of hospital admissions for patients with glioma who tested positive or negative for COVID-19 was similar, but the rate of complications among negative patients was higher.²³ Observations of the Polish database over time may answer the question of whether the decrease in trends is just a temporary situation or a long-term effect.

The trend observed for the total number of procedures and diagnoses correlates with the subgroup analysis. Although the trend for both resection and biopsy procedures showed a decrease, the mean volume of resections per year remained stable. The number of biopsy procedures seems to represent a general change in neurosurgical practices across most departments. The shift in the availability of ORs and ICUs forced medical providers to focus on the most critical patients (i.e., those experiencing trauma or oncological issues).^{3,5,6,19} This, in part, may be explained by a decrease in biopsy procedures that were more likely to be omitted in patients treated from the beginning with resection or allocated to palliative care.

Pituitary adenoma surgery is a particularly interesting neuro-oncological procedure from the perspective of COVID-19. It has been reported that, in the years 2019–2020, the decrease in the use of this procedure was 10.5%, similar to the general decrease in neuro-oncological surgery. The treatment of pituitary lesions is mainly transsphenoidal and, in the early part of the pandemic, was expected to present a higher risk for surgical personnel.²⁴ However, the implementation of safety protocols appeared to provide a safe way for treatment in many countries.^{25–28} This effective shift of the surgical organization most likely prevented a more visible change in the number of operated patients.

Length of stay represents procedural organization and is reflective of the general push to shorten in-hospital treatment. Previously, an ongoing decrease in LOS was observed in 2020. This decrease in hospitalization time is a natural consequence of the pandemic restrictions and the implementation of social distancing. It is interesting to note that the change in the number of procedures and diagnoses is statistically insignificant; however, when taking into consideration the general trend, it turned out to be significant for both of them but the LOS for diagnosis did not change. It seems that ongoing improvements in the quality of care did not enable medical staff to perform more procedures at the same time, which is represented by the decreased number of procedures. It is also interesting to note that the LOS for oncological diagnosis was longer than that for procedures in each of the analyzed years. This may be because the cases reported with oncological procedures had unfinished diagnostic workups.

The overall reaction of the neurosurgical Polish medical system during the pandemic seems to have focused on malignant cases and a tendency to perform resective procedures. Unfortunately, the treatment effort has been reallocated from nonmalignant and nonemergency groups, which may represent a sort of reserve capacity in the healthcare system. Therefore, in the future, it will be necessary to better prepare the logistics of treating infectious patients without destabilizing the treatment of “common” diseases in the event of another pandemic or other comparable overload of the healthcare system. In addition, there is a rationale to try to increase the efficiency of oncological diagnostics and qualification for procedures in oncological surgery by increasing the role of expert committees that can assist with setting the time priority for procedures. It is difficult to interpret the slight trend towards a decrease in the number of diagnoses and neuro-oncological procedures already present in the years preceding the pandemic. This observation will need to be assessed taking into account the data from subsequent years, which may allow for the identification of the cause.

Limitations

Several limitations of this study stem from the use of different types of medical reporting systems throughout Poland. The different ways of coding may produce a number of patient cases not included in this report. Also, the NFZ database only includes the most frequently coded procedures and diagnoses. However, it can be assumed that local coding protocols have remained unchanged throughout the years; therefore, the published data represent general trends in the country that are representative of all medical centers. Thus, the trends are more valuable to assess than the total numbers provided. Different codes represent procedures and diagnoses, and are secondary to reporting protocols that differ throughout the country.

The NFZ database reports only the most common ones; hence, those less often used or those unspecific or indirectly related to oncological diagnosis are not listed. Finally, some of the patients underwent more than 1 procedure. Due to these factors, we decided to group diagnoses and procedures to achieve more comprehensive results for analysis.

An important limitation of the current study is also the relatively small sample size. The NFZ database contains only annual observations from 2010, but they are not complete in the years 2010–2014.

Conclusions

The decrease in the number of neuro-oncological surgeries was much lower than the general decrease in the number of oncological surgeries in Poland, mostly resulting from postponing operations on less critical cases and focusing on the most severely ill patients. This trend was visible when focusing on malignant diagnoses and more elective surgeries, with a decrease in acute and biopsy procedures. Further observations are needed to determine the long-term impact of these trends on oncological and nononcological treatments.

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