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Trends of stroke hospitalisation and fatality rates in young *vs.* elderly people in Poland during 2010–2019 decade

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ABSTRACT

Introduction. Since the turn of the century, epidemiological studies have shown an increase in stroke hospitalisation rates among young adults in contrast to a decline in rates seen among the older population. The aim of the present study was to investigate the trends of stroke hospitalisation rates and case fatality ratios (CFR) over the decade starting in 2010 in different age groups of the Polish population.

Material and methods. The patients were identified on the basis of the Polish National Health Fund that gathers all the data of the Hospital Discharge Registry as well as the National Cause of Death Registry of patients with stroke who were hospitalised between 2010 and 2019 and who were diagnosed according to the International Classification of Diseases — Tenth Revision (ICD-10) with haemorrhagic stroke (HS; codes I61* and I62*) and ischaemic stroke (IS; codes I63*).

Results. From a total nationwide cohort of 799,132 stroke patients (86.2% with IS and 13.8% with HS) treated between 2010 and 2019, a group of 22,329 patients (2.79%) aged 18–44 years was selected, among whom 69.6% had IS and 30.4% had HS. We documented a statistically significant increase in the IS hospitalisation rate in young adults alongside a decrease of this rate in those aged > 64. Among young adults with IS, the highest increase ($p = 0.001$) was observed for those aged 35–44 in 2019 (up to 39.2), and was significant each year starting from 2017 (2017–2019: $p < 0.01$). In the case of HS, the annual number of patients did not change significantly. In 2019 (compared to 2010), a decrease in 30-day, 90-day and 1-year CFR was noted in all age groups of patients with IS and HS. Stroke aetiology of IS was diagnosed in 60% of patients. More than 40% of patients with IS were discharged with the diagnosis of stroke of unspecified cause.

Conclusions. In the case of IS, opposite trends of hospitalisation rates in younger and older age groups were documented, with the highest increase of IS in patients aged 35–44. A decline in CFR was observed for both IS and HS in all age groups.

Key words: stroke in young adults, hospitalisation rates, fatality rates, early and 1-year outcome, time trends

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Introduction

Stroke is a global health problem that significantly affects mortality and causes prolonged disability. In Europe, stroke is the third leading cause of death, and the primary cause of permanent disability, in adults. The *Burden of Stroke in Europe* report shows that in 2017 alone, a total of 1.12 million Europeans suffered a stroke and 0.46 million died due to a stroke [1]. The authors predict a 3% increase in stroke incidents, a 27% increase in prevalent cases, and a 17% reduction in mortality by 2047. They also expect a reduction in stroke events across all age groups below the age of 70.

Stroke is a highly preventable and treatable disease and the potential exists to reduce the burden of stroke. In recent decades, a decrease of stroke incidence has been observed in general. Yet paradoxically, population-based epidemiological studies have shown an increasing incidence of stroke in young adults [2]. Contradicting this last observation, a study carried out in Sweden [3] has documented fewer stroke cases in 2017 compared to 1999 in **all** age groups. Similar results have been presented by other researchers, reporting an overall decline of stroke incidence in people aged 34–104 years [4–6].

The incidence of stroke in persons aged < 45 ranges from 5 to 15 per 100,000 person-years in Europe, and up to 20 per 100,000 person-years in most North American and Australian populations. This discrepancy is mainly attributable to an increase of ischaemic stroke (IS) in contrast to the much more stable number of intracerebral haemorrhagic stroke (HS) incidences [4, 7–10]. These differences may explain the differences in the prevalence of stroke in young adults. According to some studies carried out in Poland, an 8% decrease in hospitalisation rate from 169/100,000 population in 2009 to 157/100,000 in 2013 was also observed [11].

However, the first stroke incident might occur at a younger age and might depend on different factors — this is mostly related to prior vascular pathology caused by so-called 'diseases of affluence' [4, 8–10]. The risk of stroke increases with age, and is highest in patients over 65. While the prevalence of certain vascular risk factors has been declining in the elderly population (e.g. smoking), the prevalence of such modifiable vascular risk factors as hypertension, smoking, obesity and dyslipidemia has been increasing among young adults. Approximately 35% of young ischaemic stroke patients were diagnosed with hypertension, 50–60% had dyslipidemia, and 50% reported themselves as smokers [12]. The Stroke in Young Fabry Patients, a large prospective European cohort study, showed that abdominal obesity was the most prevalent risk factor, more often among women (73%) than men (64%) [12]. The increased risk of stroke in young adults is related not only to factors typical of older groups, but also to some which occur rarely, such as genetic factors, autoimmune diseases, malignancy, atrial septal defect, and drug abuse [12, 14, 15].

Data regarding the incidence of stroke in young adults comes mostly from countries with the highest socio-demographic index (SDI) which is associated not only with a higher risk of comorbidities, but also with lifestyle factors. Ischaemic stroke in young adults has been increasing since the 1980s, something which has occurred in parallel with more frequent substance abuse and behavioural risk factors such as low physical activity and excessive alcohol consumption. Other age-specific risk factors, such as the use of oral contraceptives, may also increase the risk of ischaemic stroke. The improved stroke care introduced in developed countries, a higher capability for fast diagnosis and intervention, as well as better general knowledge about stroke symptoms, may have improved the process of diagnosis in the younger population and, by these means, brought about a decrease in the number of stroke incidences among young adults [16, 17].

In Poland, a network of hospital stroke units has been developed since 2002. Most patients with first-ever ischaemic and recurrent stroke are treated there according to the guidelines of the Polish Neurological Society [11, 18]. During the last decade (2010–2019), the number of stroke patients treated in stroke units increased. Thrombolytic treatment (rtPA) was introduced as the therapy of IS in 2004 by the National Programme of Cardiovascular Diseases, POLKARD, and from 2009 it has been financed by the National Health Fund. Since that time, the percentage of patients treated with rtPA has been systematically growing [11, 16, 19]. The aim of the present study was to investigate trends in hospitalisation rates, the frequency of rtPA therapy and the fatality ratio over the 2010s in different age groups of Polish patients suffering from ischaemic or haemorrhagic stroke, especially among people below the age of 45.

Material and methods

Source of data

The data used in the article was obtained from the resources of the National Health Fund and includes patients using healthcare in Poland in 2010–2019 in hospital settings. In the Polish healthcare system, almost all patients are insured, and according to the guidelines of the Polish Neurological Society each patient with acute stroke should be immediately hospitalised and treated in a stroke unit. Stroke diagnostics and therapy procedures are fully financed by the National Health Fund and therefore more than 90% of patients are treated in state hospitals (there are no stroke units in private hospitals).

The database contains demographic data (age and sex), information on the time and place of hospitalisation, and the type of diagnostic and therapeutic procedures used, including thrombolytic therapy. Information about mortality was obtained from the Ministry of Digital Affairs, and the data contains information about the time of death. The source of the data about the population in Poland is the database of the Central Statistical Office.

The starting point for analysis was the selection of a cohort of 799,132 patients who were hospitalised in Poland between

2010 and 2019 due to ischaemic stroke or haemorrhagic stroke according to ICD-10. In this work, patients with the main diagnosis of **different** types of strokes were analysed: ischaemic stroke according to ICD-10 I63 with all subtypes* and haemorrhagic stroke diagnosed according to ICD-10 as I61 — intracerebral haemorrhage with all subtypes and I62 — non-traumatic haemorrhage with all subtypes**. The population of patients was divided into three age groups: 18–44 years, 45–64, and > 64 years. This was because the main aim of our study was a comparison of the differences between younger and older populations regarding incidence and case fatality.

We decided to exclude subarachnoid haemorrhage (SAH) from our study. Firstly, patients with SAH are treated not only in stroke units or neurological departments but also in neurosurgery units. In our nationwide data it is possible to put one main diagnosis (the most important one in the doctor's opinion) and some additional diagnoses, but only one is formally required. Secondly, in other studies an increase has been observed in the incidence of ischaemic stroke in contrast to a stable incidence of intracerebral haemorrhagic stroke (HS) or subarachnoid haemorrhage (SAH) [14]. The number of hospitalisations was presented as annual hospitalised rates per 100,000 persons.

Age-standardised rates were calculated by taking the number of patients with stroke in the particular age group, and multiplying by 100,000 to get age-specific rates and then multiplying by the standard European population in this age group, applied by the World Health Organisation [20]. Fatality was calculated as the number of patients who died within 30 days, 90 days, and 12 months of admission. Case fatality ratio (CFR) was calculated as the proportion of the number of deaths in relation to the number of cases each year. The number of first-ever strokes (FES) was calculated based on the first admission of individual patients in each year, excluding recurrent strokes in the same or subsequent years, whereas the number of stroke admissions was the number of hospitalisations each year.

Statistical analysis

The analysis was performed using linear regression in the RStudio programme with the use of the R programming language (R version 3.6.2), with the lme4 package. The regression model was developed considering the intragroup (age group) and intergroup (year) effects. Since almost all the groups were consistent with the normal distribution, a decision not to normalise the data by logarithmisation was made. The Nelder Mead optimising algorithm was used for calculating the model. Two models were created — for the younger groups: 18–24, 25–34, and 35–44, and for the older groups: 45–54, 55–64, 65–74 and over 74 so that the results would be comparable with those previously published e.g. [7, 8, 10, 12, 14] suggesting a different aetiology of stroke in patients with a mean age of up to 44.

Results

Hospitalisation and treatment rates

The baseline characteristics of the study population are set out in Table 1. From 2010 to 2019, a total of 799,132 patients with stroke were admitted to hospital in Poland. Of those, 688,987 (86.2%) had ischaemic stroke (IS) and 110,145 (13.8%) had haemorrhagic stroke (HS). Every year, there was a decrease in the number of strokes, in total strokes ($MD_{interyear}$ = 709 cases), in ischaemic strokes from 76,263 in 2010 to 70,463 in 2019 (Tab. 2; $MD_{interyear}$ = 644 cases), and, to a lesser extent, in haemorrhagic strokes from 11,306 in 2010 to 10,719 in 2019 (Tab. 3; $MD_{interyear}$ = 65 cases). In the group with IS, there were 667,666 with FES and in the group with HS there were 103,849. In total, the proportion of males was relatively stable and ranged from 48.10% in 2010 to 50.9% in 2019. The mean age of the patients was 72.19 (± 12.61); patients with IS M_{age} = 72.98 (± 12.10) and patients with HS M_{age} = 70.11 (± 13.66).

From the total nationwide cohort of 22,328 (2.79%) patients with ischaemic or haemorrhagic stroke aged 18–44,

Table 1. Total stroke hospitalization rates in Poland 2010–2019

Year	No. of patients (total)	Age (M & SD)	Sex (males %)	No. of patients (IS)	No. of patients (HS)
2010	87,569	69.53 (11.80)	48.10%	76,263	11,306
2011	88,807	69.86 (12.17)	48.30%	77,400	11,407
2012	89,677	68.41 (14.25)	48.70%	78,095	11,582
2013	88,753	71.28 (12.48)	48.40%	77,215	11,538
2014	87,050	71.96 (12.40)	48.80%	75,427	11,623
2015	85,673	72.22 (13.18)	49.20%	74,121	11,552
2016	84,137	73.21 (12.89)	49.90%	72,891	11,246
2017	84,293	73.52 (12.68)	50.10%	73,116	11,177
2018	83,914	74.35 (12.35)	50.40%	72,714	11,200
2019	81,182	72.71 (12.05)	50.90%	70,463	10,719
All years	799,132	72.19 (12.61)	49.15%	688,987	110,145

Data presented as raw values (number of patients hospitalised each year), mean age with standard deviation and percentage of males; number of patients hospitalised each year is not a sum of all patients due to recurrent strokes. HS — haemorrhagic stroke; IS — ischaemic stroke; M — mean; SD — standard deviation

Table 2. Changes in number of patients with IS in age groups 18-44, 45-65 and > 65 in period from 2010 to 2019

Year	18–44	45–65	> 65	Total
2010	1,353	35,511	39,399	76,263
2011	1,381	35,792	40,227	77,400
2012	1,496	48,699	27,900	78,095
2013	1,463	34,824	40,928	77,215
2014	1,581	33,393	40,453	75,427
2015	1,545	32,186	40,390	74,121
2016	1,590	31,482	39,819	72,891
2017	1,739	31,144	40,233	73,116
2018	1,760	30,841	40,113	72,714
2019	1,847	29,609	39,007	70,463

Table 3. Changes in number of patients with HS in age groups 18-44, 45-65 and > 65 in period from 2010 to 2019

Year	18–44	45–65	> 65	Total
2010	669	3,993	6,644	11,306
2011	660	3,996	6,751	11,407
2012	667	4,056	6,859	11,582
2013	652	3,801	7,085	11,538
2014	638	3,767	7,218	11,623
2015	648	3,672	7,232	11,552
2016	670	3,510	7,066	11,246
2017	691	3,337	7,149	11,177
2018	727	3,301	7,172	11,200
2019	681	3,129	6,909	10,719

Table 4. Percentage of ischaemic strokes (IS) and haemorrhagic strokes (HS) each year in two age groups: 18–44 and 45–74+

	18–44		45–74+	
Year	HS	IS	HS	IS
2010	35.4%	64.6%	12.7%	87.3%
2011	35.6%	64.4%	13.1%	86.9%
2012	35.2%	64.8%	13.3%	86.7%
2013	34.5%	65.5%	13.7%	86.3%
2014	32.1%	67.9%	14.2%	85.8%
2015	33.0%	67.0%	14.4%	85.6%
2016	33.6%	66.4%	14.5%	85.5%
2017	31.8%	68.2%	14.5%	85.5%
2018	33.3%	66.7%	14.6%	85.4%
2019	28.9%	71.1%	13.8%	86.2%
All years	33.2%	66.8%	13.8%	86.2%

70.7% were women of a mean age of 34.28 (± 6.98) and 29.3% were men of a mean age of 37.19 (± 6.18). In this group there were 15,782 (69.59%) patients with IS and 6,896 (30.41%) with HS. Such a proportion (70:30) is characteristic of young adults with stroke, whereas in the elderly the proportion is 85:15 (Tab. 4).

Age-standardised rates per 100,000 with confidence intervals (95% CI) for IS and HS are set out in Tables 5 and 6. Decreases of age-standardised hospitalisation rates were documented in both types of stroke, in IS from 378.5 in 2010 to 286.1 in 2019 (–23%), and in HS from 55.39 to 43.97 (–20.6%). At the same time, patients with ischaemic stroke were increasingly hospitalised in stroke units: from 82.8% in 2010 to 92.4% in 2019. The percentage of patients with HS treated in SU (69–72%) did not change between 2010 and 2019.

The frequency of rtPA therapy use in patients with IS increased systematically each year, and exceeded 20% in 2019. This trend occurred in all age groups, but the youngest patients (aged 18–44) were treated with rtPA the most frequently. However, a comparison between 2010 and 2019 shows that the highest difference was observed in the oldest group, where the percentage of patients treated with rtPA almost quadrupled from 5.3% to 19.3% (Tab. 7).

Probability of ischaemic stroke in age groups

The linear regression model was estimated with 95% confidence interval and for model with interaction effect between the age group and the year used as predictors, as well as between the age group and the year, with admissions in each group in 2010 as the intercept.

Intergroup comparison showed greater variability in the number of hospitalisations among younger groups than in the older groups over the years. A positive trend was observed for the relative change in younger groups, but not in all of them. An increase in the percentage of change was shown in the 18–24 group, with the highest relative change of 27.78% in 2019 compared to 2018, while for the 25–34 group in 2019 it slightly decreased, from 10.94% between 2017 and 2018 to 5.63% between 2018 and 2019, whereas in the 35–44 group, the change was the greatest between 2016 and 2017 (12.28%) and between 2018 and 2019 when it amounted to 3.41%. In older groups, a decreasing trend was observed in almost all the groups and was the most pronounced between 2018 and 2019 in the 75+ group (–5.54%) and the 55–64 group (–5.04%), whereas in the 65–74 group, there was a slight increase (1.04%).

Ischaemic strokes in younger groups

The interaction model for comparisons of each age range vs. each year (2010–2019) to all the admissions of younger groups showed that there were significant ($p < 0.001$) differences of estimated values for an interaction effect in the 35–44 group. The strongest effect was observed for this group in 2019 (up

Table 5. Ischaemic stroke (I63) — age-standardised hospitalisation rates per 100,000

	Hospitalisations	SU hospitalisations	SU (%)	FES	FES (%)
2010	378.48 (376.63–380.34)	313.32 (311.63–315.01)	82.8%	350.70 (348.91–352.49)	92.7%
2011	363.60 (361.76–365.43)	300.58 (298.91–302.25)	82.7%	322.71 (320.99–324.44)	88.8%
2012	358.50 (356.66–360.33)	303.59 (301.90–305.27)	84.7%	308.79 (307.09–310.49)	86.1%
2013	346.35 (344.52–348.17)	297.05 (295.37–298.74)	85.8%	291.55 (289.88–293.23)	84.2%
2014	329.28 (327.49–331.07)	289.14 (287.46–290.82)	87.8%	273.29 (271.66–274.93)	83.0%
2015	316.27 (314.50–318.05)	282.66 (280.97–284.34)	89.4%	260.03 (258.42–261.64)	82.2%
2016	302.09 (300.32–303.85)	270.67 (269.00–272.34)	89.6%	235.16 (233.61–236.72)	77.8%
2017	296.31 (294.55–298.07)	269.64 (267.95–271.32)	91.0%	229.12 (227.57–230.67)	77.3%
2018	289.21 (287.45–290.97)	264.96 (263.27–266.65)	91.6%	221.84 (220.30–223.39)	76.7%
2019	286.13 (284.36–287.90)	264.40 (262.70–266.11)	92.4%	214.68 (213.15–216.22)	75.0%

Data presented as age-standardised values per 100,000 of population with 95% confidence interval. FES — first-ever stroke; SU — number of admissions to stroke units

Table 6. Intracerebral haemorrhage (I61-I62) — age-standardised hospitalisation rates per 100,000

	Hospitalisations	SU hospitalisations	SU (%)	FES	FES (%)
2010	55.39 (54.66–56.12)	38.29 (37.69–38.89)	69.1%	48.08 (47.41–48.76)	86.8%
2011	52.88 (52.17–53.59)	36.60 (36.01–37.19)	69.2%	44.57 (43.91–45.22)	84.3%
2012	52.37 (51.66–53.09)	37.02 (36.43–37.62)	70.7%	43.48 (42.83–44.14)	83.0%
2013	51.80 (51.08–52.51)	36.37 (35.78–36.97)	70.2%	41.89 (41.25–42.53)	80.9%
2014	50.51 (49.80–51.22)	36.39 (35.78–36.99)	72.0%	40.36 (39.72–40.99)	79.9%
2015	49.30 (48.59–50.01)	35.55 (34.95–36.15)	72.1%	39.67 (39.03–40.30)	80.5%
2016	46.96 (46.26–47.67)	32.71 (32.13–33.29)	69.7%	35.45 (34.84–36.06)	75.5%
2017	45.60 (44.90–46.30)	32.53 (31.95–33.12)	71.3%	34.56 (33.96–35.17)	75.8%
2018	45.09 (44.39–45.79)	31.94 (31.36–32.53)	70.8%	33.68 (33.07–34.28)	74.7%
2019	43.97 (43.27–44.66)	30.52 (29.94–31.09)	69.4%	32.47 (31.87–33.07)	73.8%

Data presented as age-standardised values per 100,000 of population with 95% confidence interval. FES — first-ever stroke; SU — number of admissions to stroke units

Table 7. Ischaemic stroke (I63) — frequency of rtPA therapy use; total and in different group of patients: 18–44, 45–65, > 65

	rtPA	18–44	45–65	> 65
2010	5.5%	9.7%	6.3%	5.3%
2011	6.3%	10.9%	7.4%	6.0%
2012	7.2%	12.2%	8.5%	6.8%
2013	9.1%	16.3%	11.0%	8.6%
2014	11.3%	18.3%	12.8%	10.9%
2015	12.0%	20.6%	14.5%	11.4%
2016	14.5%	21.0%	16.9%	13.9%
2017	16.6%	26.4%	19.4%	15.9%
2018	17.9%	28.3%	20.8%	17.1%
2019	20.3%	31.6%	24.2%	19.3%

Data presented as age-standardised values per 100,000 of population with 95% confidence interval. rtPA — number of admissions in which thrombolytic treatment was used

to 39.2), and it was significant ($p = 0.001$) each year from 2017 onwards (2017, 2018, 2019: $p < 0.01$). Moreover, a statistically significant increase in the number of strokes in this group was observed from 2017, which means that in recent years the risk of stroke has increased in people aged from 35 to 44. The conditional R-squared was 0.849, which means that the model explains the analysed phenomenon in 84.9%.

Therefore, on the basis of the developed model, we conclude that in years to come, the risk of ischaemic stroke will increase in the group of people aged 34–44. In recent years, there has also been an increase in the risk of ischaemic stroke in people aged 18–24 and 25–34, although statistical significance has not been achieved in these groups (Fig. 1).

Strokes in older groups

As in the younger groups, the model for the older groups was developed by establishing the number of cases in 2010 as the intercept. Statistical significance was not reached in any of the groups. In the group of the oldest people, it can be seen that estimates have been decreasing in recent years, and in 2019 this decrease reached the value of –220, but this decrease is not significant enough to predict the risk of stroke (Fig. 2). On the basis of the analysis performed, it is not possible to infer an increase or a decrease in the probability of stroke occurrence in subsequent years.

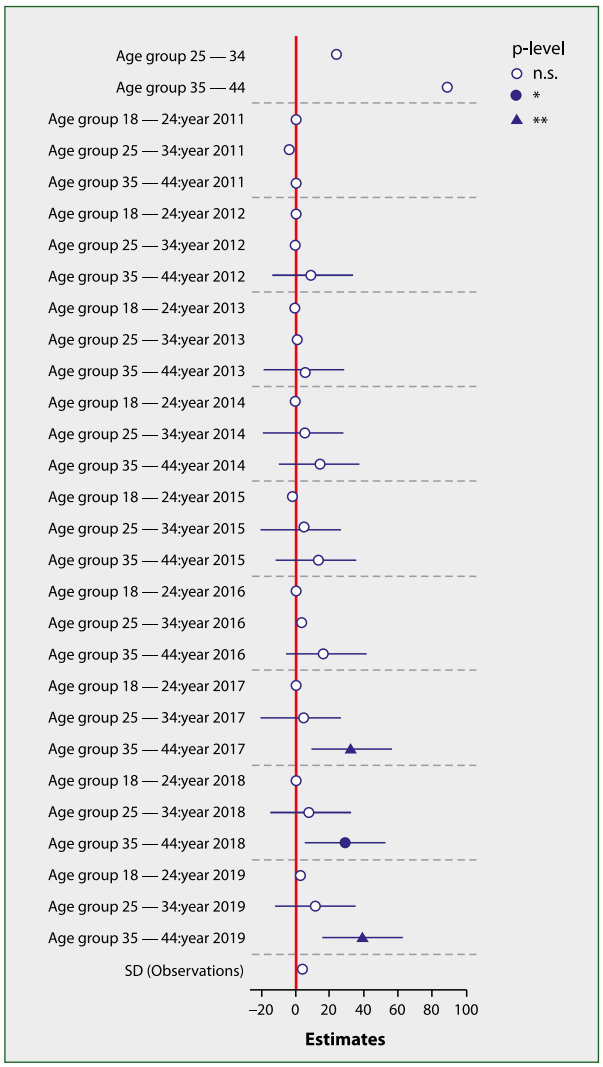

Figure 1. Interaction model for admission rates in younger groups

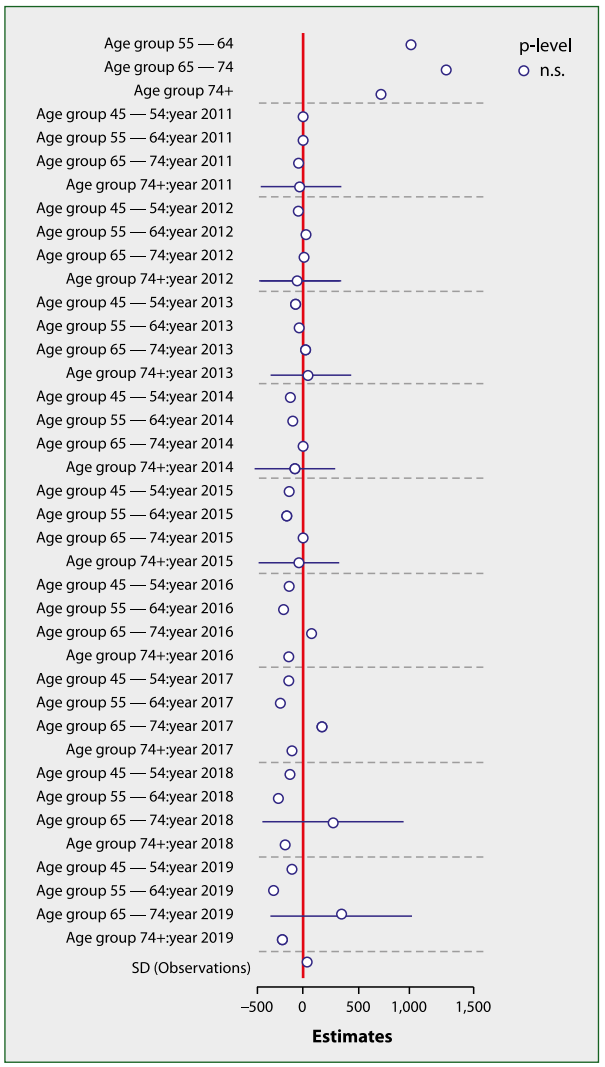

Figure 2. Interaction model for admission rates in older groups

Table 8. Ischaemic stroke (I63) — case fatality ratio

Year	30-day	90-day	1-year
2010	0.16	0.23	0.32
2011	0.17	0.23	0.32
2012	0.16	0.23	0.31
2013	0.16	0.23	0.31
2014	0.15	0.22	0.31
2015	0.16	0.23	0.31
2016	0.15	0.22	0.31
2017	0.15	0.22	0.30
2018	0.15	0.21	0.29
2019	0.14	0.20	0.28

Table 9. Intracerebral haemorrhage (I61-I62) — case fatality ratio

Year	30-day	90-day	1-year
2010	0.41	0.47	0.55
2011	0.42	0.48	0.54
2012	0.41	0.47	0.53
2013	0.41	0.48	0.54
2014	0.40	0.47	0.53
2015	0.40	0.47	0.53
2016	0.39	0.47	0.53
2017	0.39	0.46	0.52
2018	0.38	0.45	0.52
2019	0.37	0.44	0.50

Table 10. Intracerebral haemorrhage (I61-I62) fatality in specific age groups

	18–44			45–65			> 65		
Year	30-day	90-day	1-year	30-day	90-day	1-year	30-day	90-day	1-year
2010	0.24	0.26	0.29	0.36	0.4	0.46	0.45	0.54	0.62
2011	0.27	0.3	0.32	0.35	0.38	0.43	0.47	0.55	0.63
2012	0.26	0.28	0.3	0.34	0.38	0.42	0.46	0.54	0.62
2013	0.22	0.25	0.28	0.35	0.39	0.43	0.46	0.55	0.62
2014	0.25	0.27	0.29	0.34	0.39	0.42	0.44	0.53	0.60
2015	0.23	0.25	0.27	0.34	0.38	0.42	0.45	0.53	0.61
2016	0.24	0.27	0.3	0.32	0.37	0.41	0.45	0.53	0.61
2017	0.23	0.25	0.27	0.31	0.35	0.4	0.44	0.53	0.60
2018	0.24	0.26	0.29	0.31	0.35	0.4	0.43	0.52	0.60
2019	0.24	0.26	0.28	0.29	0.34	0.38	0.42	0.5	0.57

Table 11. Percentage of ischaemic stroke subtypes in patients under 45 years

Year	I63	I63.0	I63.1	I63.2	I63.3	I63.4	I63.5	I63.6	I63.8	I63.9
2010	3.0%	2.9%	1.1%	2.9%	17.2%	6.8%	17.8%	1.6%	17.5%	29.2%
2011	1.5%	2.6%	1.3%	3.1%	17.3%	8.9%	17.6%	2.3%	18.7%	26.7%
2012	2.1%	3.2%	1.0%	3.1%	19.4%	8.2%	16.5%	2.5%	17.0%	27.0%
2013	2.7%	1.9%	0.6%	1.6%	23.5%	10.1%	15.6%	2.8%	16.5%	24.6%
2014	2.5%	2.8%	1.4%	2.6%	23.7%	9.5%	14.0%	3.4%	15.8%	24.3%
2015	3.5%	2.7%	0.7%	2.2%	24.8%	11.9%	12.3%	3.5%	15.2%	23.2%
2016	3.4%	1.9%	0.8%	2.5%	26.9%	11.9%	13.1%	3.0%	13.4%	23.2%
2017	4.0%	2.6%	1.0%	2.6%	26.9%	13.7%	12.0%	2.9%	12.9%	21.3%
2018	4.4%	2.8%	1.0%	2.3%	29.4%	15.8%	8.7%	3.7%	11.0%	21.0%
2019	4.2%	2.0%	0.7%	2.2%	28.1%	14.3%	11.2%	3.4%	11.7%	22.3%

I63 — cerebral infarction; I63.0 — cerebral infarction due to thrombosis of precerebral arteries; I63.1 — cerebral infarction due to embolism of precerebral arteries; I63.2 — cerebral infarction due to unspecified occlusion or stenosis of precerebral arteries; I63.3 — cerebral infarction due to thrombosis of cerebral arteries; I63.4 — cerebral infarction due to embolism of cerebral arteries; I63.5 — cerebral infarction due to unspecified occlusion or stenosis of cerebral arteries; I63.6 — cerebral infarction due to cerebral venous thrombosis, nonpyogenic; I63.8 — other cerebral infarction; I63.9 — cerebral infarction, unspecified

Fatality ratio

In IS and HS, 30-day, 90-day and 1-year CFR decreased when comparing change between 2010 and 2019. In IS, 30--day CFR decreased from 16% to 14%, 90-day from 23% to 20%, and 1-year from 32% to 28% (Tab. 8) while in HS (Tab. 9) decreases were respectively 30-day — 41% to 37%, 90-day 47% to 44%, and 1-year 55% to 50%. The highest decrease of CFR was observed in 30-day fatality in all indicators. In IS, it was 12.5%, and in HS it was 9.8%. In SU IS, CFR was relatively stable and lower than in all units, although the differences were not very high.

The data shows a decline in fatality due to ischaemic stroke in the elderly (15% decrease between 2010 and 2019 in 30-day, 13.8% decrease in 90-day, and 15% decrease in 1-year fatality). Over the same period, an increase was observed in younger people. However, this increase may be due to the relatively low number of deaths among young people (CFR of 0.04 in 2019, equivalent to 52 death cases), meaning that a small difference in absolute terms translated into a large percentage difference. In haemorrhagic strokes, a decreasing trend in CFR was observed in all groups and in all analysed periods (Tab. 10).

The diagnosis of different types of stroke (i.e. IS or HS) was performed according to ICD-10 (Tab. 11). In total, in young and old alike, the most common type of IS was cerebral infarction due to thrombosis of cerebral arteries (I63.3). The diagnosis of this type of stroke increased from 2010 to 2019 in both age groups of patients (in young adults from 7.2% to 28.1% and in older people from 17.8% to 28.7%.) The second most common type of stroke was I63.4 cerebral infarction due to embolism, with growth respectively from 6.8% to 14.3% in young adults and in older people from 8.6% to 19.3%.

The positive observation from this analysis is that there was an increased diagnosis of stroke due to vein or sinus thrombosis. Cerebral vein thrombosis, which belongs to a rare type of stroke, was diagnosed among 1.6% of young adults in 2010 but in 3.4% in 2019, which indicates greater understanding regarding this type of stroke and better diagnosis. Unfortunately, similarly in young adults and in the elderly, the most common diagnosis in our study (40% of patients) was cerebral infarction unspecified (I63.9), cerebral infarction due to unspecified occlusion or stenosis of cerebral arteries (I63.5), and other cerebral infarction (I63.8). However, it

should be emphasised that the number of patients with such a diagnosis declined during the study period — in young adults from 64.5% in 2010 to 45.25% in 2019, and in older people from 64% to 45.2%. It should be stressed that the diagnosis of cerebral infarction due to cerebral venous thrombosis (I63.6) was diagnosed most frequently in young adults — 3.4% more than in the population above 44 y/o. Lack of carotid dissection diagnosis, which is quite common among young people, is connected mainly with the coding system used in ICD-10. Stroke caused by extracranial artery dissection may be coded as I63.0, I63.2 or I63.8.

Discussion

Our study proves that in Poland — similarly to other European countries and the United States — contradictory trends regarding IS especially have been observed [4, 8–11]. In the study period, from 2010 to 2019, we documented a decline of stroke hospitaliaation rates in the elderly and an increased number of IS in young adults aged between 18 and 44. This age limit has been used in the majority of studies in this area [7, 9, 12], although some researchers have included patients up to 50 years , or even those aged 18–55 [8]. The patients included in the study were treated mainly in stroke units, and they were diagnosed according to the guidelines of the Polish Neurological Society. However, the differences between IS and HS regarding the frequency of hospitalisation in stroke units is mainly due to the fact that the patients with HS may be treated also in ICUs or neurosurgical departments.

The proportion of young adults with stroke was 2.79% and was lower compared to previous studies, partially because they included patients up to 50 years [15, 20]. Another explanation of the lower percentage of young adults with stroke may be a false negative diagnosis that refers to patients with malignancies in whom improvements in survival over recent decades have been observed. 80% of young adults diagnosed with cancer can expect to survive at least five years from diagnosis. In this group of patients, the sudden development of neurological deficit is more often diagnosed as a cancer complication than as stroke. Consequently, such persons more frequently are admitted to oncological or internal medical wards.

The opposing trends of hospitalization rates, i.e. an increase in young adults and a decrease among people aged > 65, observed in Poland, have also been reported in other European countries and the United States [4, 8–11].

In the entire Polish population, the hospitalization rates for ischaemic stroke decreased by 7.61% between 2010 and 2019, but during that time an opposite trend in the group of young adults (18–44) was observed. An especially statistically significant increase of hospitalisation rates up to 39.2% was noted between 2017 and 2019 among patients aged 35–44. Analogous results from worldwide data show an increase of up to 40% [7]. As presented in other studies [21], these changes have mainly been attributed to the increase of the hospitalisation rates of ischaemic stroke in contrast to a stable hospitalisation rate for haemorrhagic strokes. Increasing rates of hospitalisation in men (+36.91%) and in women (+36.02%) aged 18–44 were in contrast to hospitalisations due to intracerebral haemorrhage in which hospitalisation rates showed a tendency to decrease in women (–16.82%) but to increase in men (+12.28%). This latter tendency remained relatively stable in the study period. In recent years, there has also been an increase in the risk of ischaemic stroke in people aged 18–24 and 25–34, although statistical significance has not been achieved in these groups. These observations correspond to the results of *The Teenage and Young Adult Cancer Survivor Study* (TYACSS), in which males had a significantly higher risk of cerebrovascular events than females, particularly among survivors of a CNS, head or neck tumour [22].

The cause of the increased hospitalisation rates of stroke in young adults has not been fully explained, although several hypotheses have been put forward. It has been suggested, for example, that differences between countries may be related to differing levels of organisation of stroke care, especially in terms of building people's awareness regarding vascular risk factors by promoting physical activity, healthy diet, and regular blood pressure control). In Poland, promoting knowledge on stroke risk factors is mainly directed towards patients older than 44 [23]. Another explanation relates to the improvements in, and better accessibility of, neuroimaging procedures. These include not only computed tomography (CT), but also the wider use of magnetic resonance imaging (MRI), particularly in young adults, which may improve differential diagnosis between transient ischaemic attacks (TIA) and stroke. However, the majority of researchers highlight — as the main cause — the risk factors related to lifestyle: smoking, drinking, and illicit substance abuse [10, 20, 22]. In Poland, the prevalence of such risk factors has been increasing each year. Also the high percentage of patients with untreated hypertension among young people, together with the common habit of smoking, low levels of physical activity and high levels of obesity in the young population is reflected in the high prevalence of cardiovascular diseases such as myocardial infarction and atrial fibrillation that, according to many clinicians, increase the risk of cerebrovascular events in young people [8, 9, 24–26]. In the study by Boot et al. from 2020 [12], 50–60% of stroke patients had dyslipidemia. In Poland, 80% of patients aged 60 and over with previous stroke are overweight or obese.

The discrepancies in IS incidence between younger and older people are mainly connected to the decline in the general population of certain vascular risk factors such as hypertension, smoking, dyslipidemia, diabetes and obesity, which according to several studies have tended to increase during recent decades among young stroke patients [12]. Our present study has supported this concept, as have others analysing this area.

The most common diagnosis is of IS cerebral infarction due to thrombosis of the cerebral arteries and the second most

common is cerebral infarction due to embolism. These are the most common diagnoses of which the frequency has increased during the study period. Similarly, in the Helsinki Young Stroke Registry, cardioembolic stroke and small vessel disease were diagnosed in 18.7% and 13.9% respectively [2]. The positive observation from the present study is the increased diagnosis of stroke due to vein or sinus thrombosis. Cerebral vein thrombosis, which belongs to a rare type of stroke, has been diagnosed among young adults from 1% in 2010 up to 3% in 2019. This indicates growing knowledge of this type of stroke, and better diagnosis. As in other studies, unspecified cerebral infarction (I63.9) or other cerebral infarction (I63.8) was the most frequent diagnosis of stroke in young adults. It should be stressed that such a diagnosis was common not only in young adults, but also in the elderly. In HS, the most common diagnosis in young adults and in the elderly was a general statement that it was non-traumatic, unspecified intracerebral haemorrhage (I61.9 and I61.0).

The percentage of patients treated with intravenous thrombolysis is increasing every year. This trend is consistent with results from other countries [26, 28]. In the youngest patients, the percentage of thrombolytic therapy used was the highest, similarly to the study by Marko et al. (2020) [29], in which the percentage of patients treated with rtPA increased from 10.5% in 2006 to 21.5% in 2018 in the group < 60 years. However, in > 60 y/o, a greater increase was recorded.

Our present study has revealed, similarly to others [11, 30], a decrease of CFR in all age groups. In total, CFR was lower among young adults then in elderly.

Across the entire age spectrum, in young and in old, it is of paramount importance to recognise the cause of stroke that directly determines acute treatment, secondary prevention and outcome. Ischaemic stroke in the young often has a different aetiology from that observed in older people. The typical aetiology of ischaemic stroke according to TOAST classification has been confirmed in 46.5% in the Helsinki Young Stroke Registry [2], comprising cerebral dissection (15.5%), cardioembolic stroke (18.7%), small vessel disease (13.9%), and large artery sclerosis (8.4%). In others, the diagnosis has been described as undetermined. In the present study's cohort, the diagnosis was proved in 62%, and in 38% the patient was discharged from hospital with a diagnosis of stroke of undetermined aetiology. The tables divided into different subtypes of strokes are set out below in the supplementary materials. Lack of carotid dissection diagnosis, which is quite common in the young, is connected mainly to the coding system used in ICD-10. Stroke caused by extracranial artery dissection may be coded as I63.0, I63.2 or I63.8.

The low incidence of aetiological diagnosis of carotid dissection is connected mainly with coding. It is possible to put one main diagnosis (the most important one in the doctor's opinion) and some additional diagnoses, but only one is required For example, stroke caused by extracranial artery dissection may be coded as I63.0, I63.2, I63.8 and artery dissection may be added as a comorbid diagnosis with the codes I72.0 or I72.6. In cases of HS, the most frequent type seems to be I61.0 because of the ICD-10 structure. It should be emphasised that the classification of HS is not aetiological, but it is based on the localisation of haemorrhagic lesions. The most general diagnosis, I61, means non-traumatic cerebral haemorrhage, and I61.0 relates to intracerebral hemorrhage in the hemisphere, as in other nationwide studies, the diagnosis was classified according to ICD-10, which means that rare causes are collected in the same category as other causes. Therefore, data regarding information about rare stroke aetiology such as neurogenetic diseases, inflammatory vasculopathies, patent foramen ovale, and haematological disorders must be excluded. There is a discrepancy between clinical and nationwide based studies regarding ischaemic stroke etiology. The aetiology of ischaemic stroke in young adults is more heterogenic than in patients > 60. Such diseases as dissection of carotid or vertebral arteries or embolic aetiology due to patent foramen ovale (PFO) have been diagnosed in 50% of patients [31]. Regarding young adults, the ICD-10 classification is insufficient, as is the TOAST classification. In the case of young people (< 45) with a different aetiology than in the elderly, a separate classification should be created. In some countries like Sweden, public health interventions regarding primary stroke prevention aimed at young people have stabilised the number of strokes in the age group under 55, so it may be worth introducing such programmes in Poland [32].

Conclusions

In Poland, in young adults the probability of ischaemic stroke increased every year from 2010 to 2019 (39.2% increase compared to 2010), especially in the group of people aged 35–44 years, and this was contrary to the stable hospitalisation rates of intracerebral haemorrhage.

An estimated 2.8% of all first-ever strokes (FES) occur in people aged 18–44 years.

The heterogeneous aetiology of stroke in young adults, and the wide variety of factors that may influence the risk of stroke, mean that it is more challenging to diagnose than in older patients.

Among people under 45, the number of ischaemic strokes is still low compared to older patients, but the reversal of the trends, i.e. the annual increase of stroke occurring in younger people and the annual decline of stroke occurring in the elderly, has shown the importance of the development of primary prevention dedicated to young adults.

Limitations of study: *The main limitation of the study was the lack of data about other factors that could affect the risk of stroke, such as tobacco use, results of laboratory tests, ultrasound imaging, or illicit drug use that could allow the determination of the cause of the increasing number of hospitalisations due to stroke among people aged under 45. Nevertheless, the strengths*

of this study are a large cohort, its nationwide character, and the use of data regarding all the patients hospitalised in a period of over a decade.

Additional note to Source of Data:

*I63 — cerebral infarction; I63.0 — cerebral infarction due to thrombosis of precerebral arteries; I63.1 — cerebral infarction due to embolism of precerebral arteries; I63.2 — cerebral infarction due to unspecified occlusion or stenosis of precerebral arteries; I63.3 — cerebral infarction due to thrombosis of cerebral arteries; I63.4 — cerebral infarction due to embolism of cerebral arteries; I63.5 — cerebral infarction due to unspecified occlusion or stenosis of cerebral arteries; I63.6 — cerebral infarction due to cerebral venous thrombosis, nonpyogenic; I63.8 — other cerebral infarction; I63.9 — cerebral infarction, unspecified

**I61 — non-traumatic intracerebral haemorrhage; I61.0 — non-traumatic intracerebral haemorrhage in hemisphere, subcortical; I61.1 — non-traumatic intracerebral haemorrhage in hemisphere, cortical; I61.2 — non-traumatic intracerebral haemorrhage in hemisphere, unspecified; I61.3 — non-traumatic intracerebral haemorrhage in brain stem; I61.4 —non-traumatic intracerebral haemorrhage in cerebellum; I61.5 — non-traumatic intracerebral haemorrhage, intraventricular; I61.6 — non-traumatic intracerebral haemorrhage, multiply localised; I61.8 — other non-traumatic intracerebral haemorrhage; I61.9 — non-traumatic intracerebral haemorrhage, unspecified; I62 — other and unspecified non-traumatic intracranial haemorrhage; I62.0 — non-traumatic subdural haemorrhage; I62.1 — non-traumatic extradural haemorrhage; I62.9 — non-traumatic intracranial haemorrhage, unspecified

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