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Stroke Care Performance in the Baltic States: A Multicenter Registry-Based Observational Study

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ABSTRACT

Background: Stroke remains a major public health challenge in Europe with regional disparities. Although the Baltic states share similar demographic and socioeconomic profiles, they differ in stroke care networks and treatment infrastructure. To date, no direct cross-country comparison of stroke care has been published.

Methods: We conducted a multicenter cross-sectional analysis of ischemic stroke patients, prospectively recorded in the Registry of Stroke Care Quality (RES-Q) by 23 of 26 primary and comprehensive stroke centers across the Baltic states during at least 1 month of the first quarter of 2022. Data on demographic characteristics, stroke risk factors, acute management, and discharge destinations were compared with assess intercountry differences.

Results: A total of 897 ischemic stroke patients were analyzed: 479 from Lithuania, 294 from Latvia, and 124 from Estonia. Although atrial fibrillation (AF) rates were uniformly high (overall 37.2%), anticoagulant use at stroke onset among patients with known AF was significantly higher in Estonia (72.7%) compared with Latvia (34.9%) and Lithuania (48.8%, $p = 0.032$). Estonia reported the highest intravenous thrombolysis (IVT) rates (44.4%), whereas Lithuania achieved the highest endovascular treatment (EVT) rates (17.7%). In contrast, Latvia had the lowest recanalization therapy rates (IVT 21.1%, EVT 5.1%).

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Rehabilitation access varied strikingly: Only 2.7% of Latvian patients were transferred to inpatient rehabilitation compared with 30.5% in Lithuania and 20.2% in Estonia ($p < 0.001$).

Conclusions: This first comprehensive comparison of stroke care in the Baltic states highlights a high AF burden and important disparities in recanalization therapy and poststroke rehabilitation pathways.

Data Access Statement: The data supporting this study's findings are available from the corresponding author upon reasonable request.

1 | Introduction

Stroke is among the most significant public health concerns, profoundly impacting health-related quality of life [1]. It ranks as the second leading cause of death and the third leading cause of disability worldwide [2, 3]. Europe's aging population and increasing survival rates are expected to be associated with an absolute increase in the number of strokes in the future [4].

Although age-standardized stroke incidence rates have generally decreased across Europe, regional disparities persist. Countries in the Baltic region, for example, continue to report stroke mortality rates up to seven times higher than those in Western European countries such as France, Austria, and Belgium, despite significant reductions over the last decade [3, 5, 6].

The three Baltic states—Lithuania, Latvia, and Estonia—have comparable population demographics, path of socioeconomic development, and cardiovascular risk factor distribution [7–12]. In addition, all three report a higher prevalence and incidence of known or newly detected atrial fibrillation (AF) among stroke patients, reaching up to a staggering 48.6% of acute ischemic stroke cases [13]. This suggests a shared regional burden of this risk factor compared with other regions, usually not exceeding one-third of all cases [14].

Although often considered together, the Baltic countries have markedly different stroke care networks, treatment protocols, and healthcare infrastructure, leading to varied approaches to stroke care. For example, Estonia's island geography and lower population density have driven the development of telestroke services. In contrast, Latvia and Lithuania typically rely on on-call neurologists to assess whether a patient requires transfer to a comprehensive stroke center (CSC) for endovascular treatment (EVT). Lithuania and Estonia distinguish themselves further by maintaining a system of 24/7 operational stroke-ready hospitals, unlike Latvia, where not all CSCs offer continuous coverage for EVT [15].

Stroke care extends beyond the acute phase and requires seamless coordination across treatment, rehabilitation, and follow-up. Addressing this continuum is a central aim of the Stroke Action Plan for Europe (SAP-E) 2018–2030 [16], in alignment with the Angels Initiative, both supported by the European Stroke Organisation (ESO) [17–19]. A key element of improving stroke care quality is the use of clinical registries. The Registry of Stroke Care Quality (RES-Q), developed with this goal in mind, provides a free, internationally recognized platform to identify process gaps and support continuous quality improvement [20]. Although it primarily focuses on in-hospital care metrics, RES-Q is vital in benchmarking and standardizing stroke services worldwide. Nevertheless, few in-depth direct comparisons of stroke care among the Baltic states have been carried out to date [20].

Therefore, in this multicenter registry-based retrospective cross-sectional study involving ischemic stroke patients from Lithuania, Latvia, and Estonia, we are aimed at exploring differences in ischemic stroke patient characteristics, presenting a comprehensive snapshot of stroke care performance measures, and comparing patient discharge destinations across all three Baltic states.

2 | Methods

2.1 | Study Design and Data Source

Our international multicenter registry-based observational study was conducted in 23 of the 26 stroke-ready hospitals in the three Baltic states (Table S1). Data for at least 1 full month of consecutive ischemic stroke patients have been entered into the RES-Q registry by representatives of each stroke center for quality control purposes between January 1 and March 31, 2022. The data dictionary includes variables from the RES-Q 3.0 form and is available online [21].

2.2 | Setting

The healthcare systems of all three Baltic states operate under compulsory National Health Insurance Funds, ensuring free access to state-funded health services, encompassing primary healthcare, emergency medical services (EMS), primary and secondary prevention programs, inpatient care, prescription medications, and rehabilitation services, among others. In each country, stroke care is provided through a national network of stroke centers, strategically located to ensure patients can be admitted within the optimal therapeutic window for acute stroke interventions [15, 22, 23].

Although Lithuania, Latvia, and Estonia cover comparable land areas (65,300, 64,600, and 45,300 km², respectively), they differ significantly in terms of population size and density, with Lithuania having 2.8 million residents, followed by Latvia with 1.9 million and Estonia with 1.3 million. There are six CSCs and five primary stroke centers (PSCs) in Lithuania, three CSCs and six PSCs in Latvia, and two CSCs and four PSCs in Estonia. All suspected stroke patients in the Baltic states are required to be transferred to the nearest stroke-ready hospital, ensuring timely access to care. Patients not requiring recanalization therapy may subsequently be transferred to other hospitals for inpatient management. According to 2022 respective National Health Insurance Fund data, the proportions of ischemic stroke patients treated in dedicated stroke units were 86.1% in Estonia, 62.6% in Lithuania, and 51.1% in Latvia.

Only two of Latvia's CSCs provide 24/7 EVT coverage, whereas the third is EVT-capable only during regular working hours. Consequently, the vast majority of EVTs in Latvia are carried out at a single center. In addition, due to the Estonian island geography, two island hospitals utilize telemedicine for intravenous thrombolysis (IVT): Patient CT images are transferred to the national, nationwide imaging database and reviewed by on-call radiologists and neurologists. When additional intervention is required, patients are subsequently airlifted by helicopter to a stroke-ready hospital in Tallinn.

The distribution of the stroke-ready hospitals is shown in Figure 1. Country boundaries and road networks were derived from publicly available basemap resources that are free for use and modification [24]. These layers were superimposed on

each state's relative population density map. High-resolution population distribution data for the three countries were sourced from the WorldPop Open Population Repository (2020) [25]. Spatial analysis was conducted using QGIS (Version 3.40.0) [26].

2.3 | Ethics

The study was conducted according to the guidelines of the Declaration of Helsinki. The Lithuanian Biomedical Ethics Committee approved the study protocol (Protocol Code L-22-08/1-9). This study was reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines (see File S1).

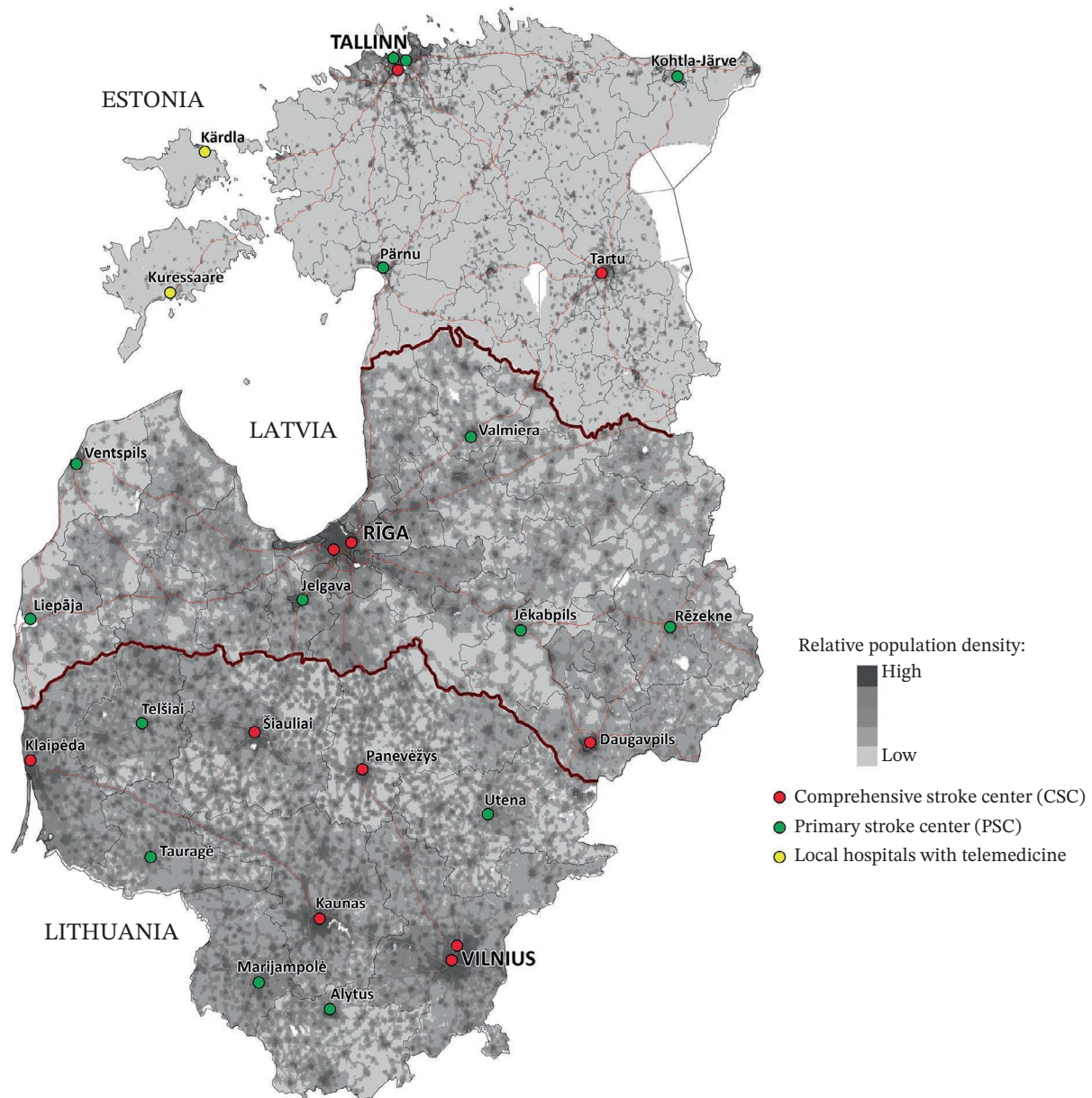


FIGURE 1 | The distribution of Lithuanian, Latvian, and Estonian primary and comprehensive stroke centers, superimposed on a relative population density map of the three Baltic states.

2.4 | Statistical Analysis

We included patients of all ages who were diagnosed with ischemic stroke and received care at one of the designated stroke centers across the Baltic states. Only patients whose clinical data were recorded in the RES-Q registry were included. Patients with hemorrhagic stroke, as well as those ultimately diagnosed with stroke mimics despite initial treatment at a stroke center, were excluded from the analysis to ensure diagnostic consistency and focus on ischemic stroke care pathway evaluation.

An available-case approach was used, whereby patients were included in analyses for variables with available data and excluded only from analyses where specific variables were missing, whereas no imputation of missing data was performed. Most of the missing values were related to nonmandatory variables, as specified in the RES-Q Standard Data Collection Form [21]. We explicitly reported the sample size for variables where > 5% of values were missing.

Discrete variables were presented as count and percentage, whereas continuous variables were presented as mean and standard deviation (SD) or median and interquartile range (IQR). We assessed the normality of variable distribution by the Shapiro–Wilk test. Based on this, quantitative variables were compared using one-way ANOVA or the Kruskal–Wallis test. We compared categorical variables using the χ^2 test and Fisher–Freeman–Halton exact test, as appropriate. Statistical tests were two-tailed, and the significance level was set at $p < 0.05$.

3 | Results

3.1 | Clinical and Sociodemographic Characteristics

A total of 479 ischemic stroke cases from Lithuania, 294 from Latvia, and 124 from Estonia were included in the statistical analysis. The median age was lowest in Lithuania at 72 years (IQR 63–80), followed by Latvia at 76 years (IQR 68–83) and Estonia at 77 years (IQR 68–83) ($p < 0.001$). There was no significant difference in patient gender composition. Median baseline stroke severity, as measured by the NIHSS at onset, was similar in Lithuania and Latvia (7 [IQR 3–13] vs. 7 [4–13], respectively) but significantly lower in Estonia (5 [2–9], $p = 0.002$), reflecting milder stroke severity in the Estonian cohort. The complete list of clinical and sociodemographic characteristics is available in Table 1.

Although there was no significant difference in the prevalence of hypertension between the Baltic states, Estonian stroke patients had significantly higher rates of hyperlipidemia (42.7%, $p < 0.001$), whereas diabetes was twice as prevalent among Lithuanian subjects (50.5%), compared with Estonians 25.8% ($p < 0.001$). In contrast, Latvian stroke patients had significantly higher rates of carotid artery stenosis (13.5%, $p < 0.001$), coronary artery disease (11.3%, $p < 0.001$), and congestive heart failure (28.6%, $p < 0.001$). The prevalence of stroke patients with AF did not differ significantly between countries, although the numbers were some of the highest in the available literature, ranging from 36.2% in Lithuania to 43.0% in Estonia.

Estonian stroke patients with previously known cardiovascular risk factors were more adherent in the use of anticoagulants (72.7%, $p < 0.001$), antihypertensives (86.5%, $p < 0.001$), and antidiabetics (68.8%, $p < 0.001$). Prestroke statin use was slightly higher than in Latvian patients with hyperlipidemia (50.9%, $p < 0.001$) but comparable with the proportion observed among Lithuanian stroke patients. Antiplatelet use before stroke onset for stroke patients without known AF did not differ significantly between countries (see Figures 2 and S1).

3.2 | Acute Stroke Treatment

Overall, 186 (38.8%), 67 (22.8%), and 61 (49.2%) ischemic stroke patients were treated with recanalization therapy in Lithuania, Latvia, and Estonia, respectively, during the study period. IVT rates were significantly higher in Estonia (44.4%) compared with Lithuania (24.8%) and Latvia (21.1%, $p < 0.001$). In contrast, EVT rates were significantly higher in Lithuania (17.7%) compared with 12.1% in Estonia and 5.1% in Latvia ($p < 0.001$).

Although the median onset-to-door and onset-to-treatment times did not differ significantly between countries, Estonia had the highest percentage of patients arriving within 60 min of symptom onset (23.1%), followed by Lithuania (14.2%) and Latvia (8.7%, $p = 0.01$). Median door-to-needle times were comparable across the countries: 27 min (IQR 20–52) in Lithuania, 38 min (IQR 23–62) in Latvia, and 33 min (IQR 18–52) in Estonia ($p = 0.12$), whereas significantly shorter door-to-groin times were achieved in Latvia at 61 min (IQR 39–100), followed by Estonia at 84 min (IQR 69–103), and Lithuania at 102 min (IQR 80–135, $p = 0.004$) (see Table 2 for a more comprehensive snapshot of timeliness metrics).

3.3 | Discharge Destinations

The median length of hospital stay differed significantly between the countries: Estonian patients had the shortest hospital stay at 5 days (IQR 3–6), whereas Lithuanian and Latvian patients both had longer stays, with a median of 8 days (IQR 6–12 and IQR 6–11, respectively). There was no statistically significant difference in in-hospital mortality rates between the Baltic states. When analyzing discharge destinations, strikingly, only 2.7% of patients in Latvia, compared with 30.5% in Lithuania and 20.2% in Estonia, were transferred to a rehabilitation center ($p < 0.001$). The majority of Latvian stroke patients (205, 69.7%) were discharged home, as opposed to 46.0% of patients in Estonia, and 30.9% in Lithuania ($p < 0.001$) (see Table 3 for a detailed summary of length of stay and discharge destinations).

4 | Discussion

Our multicenter registry-based cross-sectional study represents the first comprehensive analysis of stroke care in the three Baltic states. Firstly, we found that the prevalence of stroke patients with AF in the Baltic states was one of the highest in the available literature, ranging from 36.2% in Lithuania to 43.0% in Estonia. Second, Latvia had significantly lower overall EVT rates and the shortest door-to-groin

TABLE 1 | Clinical and sociodemographic characteristics of the ischemic stroke patient population in the three Baltic states.

	Lithuania (<i>n</i> = 479)		Latvia (<i>n</i> = 294)		Estonia (<i>n</i> = 124)		<i>p</i> value
Median age, years (IQR)	72	(63–80)	76	(68–83)	77	(68–83)	< 0.001
Age range in years							< 0.001
0–17	1	(0.2)	0		0		1
18–50	27	(5.6)	12	(4.1)	7	(5.6)	0.611
51–70	194	(40.5)	81	(27.6)	34	(27.4)	< 0.001
> 70	257	(53.7)	201	(79.7)	83	(66.9)	< 0.001
Female gender, <i>n</i> (%)	226	(47.2)	159	(54.1)	70	(56.5)	0.069
NIHSS at onset, median (IQR)	7	(3–13) ^a	7	(4–13)	5	(2–9)	0.002
Risk factors, <i>n</i> (%)							
Hypertension	93	(78.8)	244	(83.0)	96	(77.4)	0.275
Diabetes	211	(50.5) ^b	112	(38.1)	32	(25.8)	< 0.001
Hyperlipidemia	110	(25.1) ^b	93	(31.6)	53	(42.7)	< 0.001
Atrial fibrillation	169	(36.2) ^b	116	(41.3)	49	(43.0)	0.243
Known	123	(25.7)	83	(28.2)	33	(26.6)	0.759
Newly detected	46	(9.6)	33	(11.2)	16	(12.9)	0.759
Carotid stenosis ≥ 50%	32	(6.7) ^b	35	(13.5)	0		< 0.001
Congestive heart failure	61	(13.9) ^b	84	(28.6)	10	(8.1)	< 0.001
Current smoker	53	(12.1) ^b	19	(6.5)	25	(20.2)	< 0.001
Coronary artery disease	82	(18.7) ^b	87	(29.6)	14	(11.3)	< 0.001
Previous stroke	65	(13.9)	55	(15.0)	18	(14.5)	0.191
None	31	(7.1) ^b	14	(4.8)	8	(6.5)	0.440

Note: Bold values denote statistically significant results ($p < 0.05$), as stated in Methods Section 2.4.

Abbreviations: IQR, interquartile range; NIHSS, National Institutes of Health Stroke Scale.

^a $n = 293$.

^b $n = 438$.

times because most EVTs were performed at a single center. Third, only 2.7% of all Latvian ischemic stroke patients were transferred directly to inpatient rehabilitation, with most of the patients discharged home and having to undergo outpatient rehabilitation or receive social care. This discrepancy indicates an urgent need for a state rehabilitation policy review for Latvian stroke patients. Finally, the establishment of a multicountry, routine quality-monitoring baseline across PSCs and CSCs in the Baltics enables longitudinal benchmarking and targeted improvement.

Although AF affects approximately 2%–3% of the general population in Europe and North America, with prevalence sharply increasing with age, the burden of AF among acute ischemic stroke patients is considerably higher [27–31]. The prevalence of AF among acute ischemic stroke patients varies between countries, and large registry studies have shown that AF is present in 15%–38% of ischemic stroke cases, with some national cohorts,

such as in Greece, reporting prevalence rates up to 38% [32, 33]. Remarkably, hospital-based registry data from the Baltic states have documented even higher rates, with AF present in up to 48.6% of stroke patients, among the highest figures globally [34]. This is particularly striking given that the general population prevalence of AF in the region is reported to be lower than in Western Europe and North America [35]. This apparent paradox may reflect differences in stroke patient characteristics, diagnostic practices, or healthcare system factors [36]. It also reaffirms the need for targeted AF detection and management strategies in primary stroke prevention, especially in regions where stroke patients present with high rates of undiagnosed or undertreated AF.

Previous studies have speculated that a small penetration of DOACs due to the restrictive reimbursement conditions may partly explain the high prevalence of cardioembolic stroke in some of the Baltic states [13]. Until July 2022 in Lithuania,

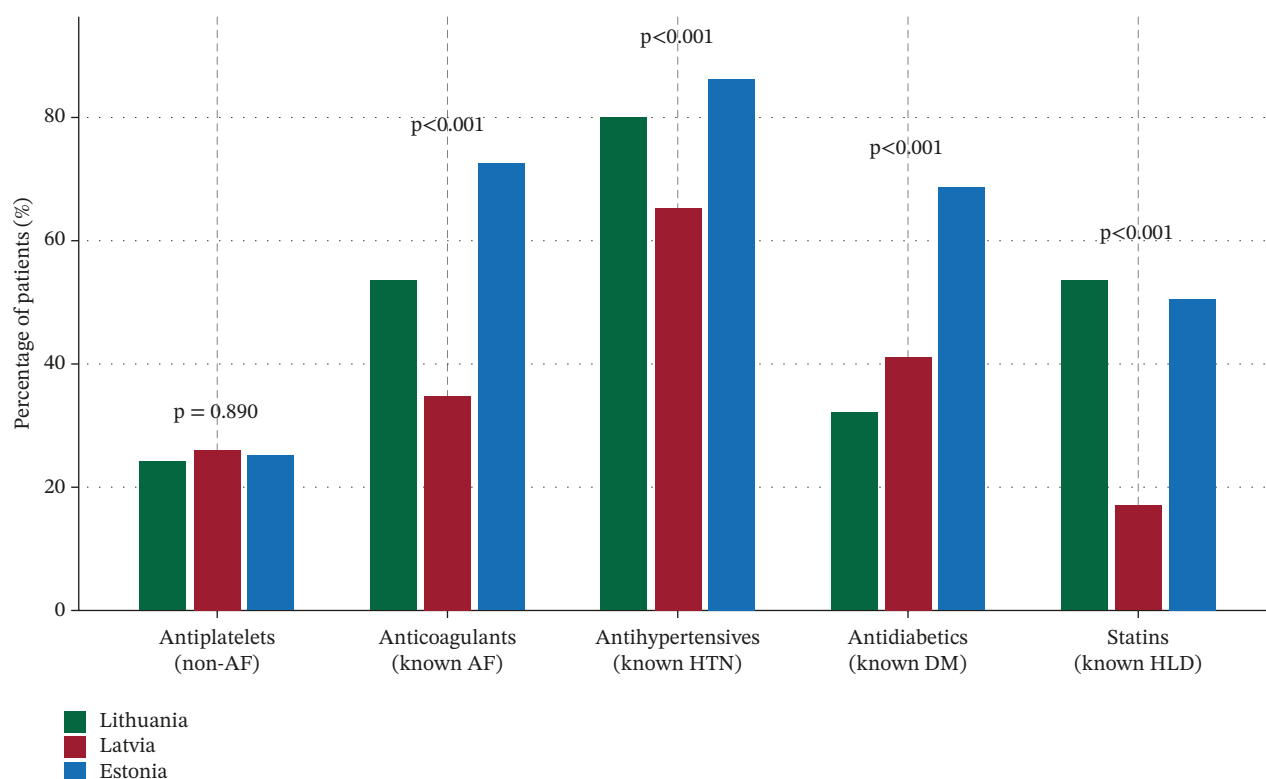


FIGURE 2 | Treatment adherence before the ischemic stroke onset by condition in each of the Baltic states. AF—atrial fibrillation, HTN—hypertension, DM—diabetes mellitus, HLD—hyperlipidemia.

DOACs used to be reimbursed only following warfarin failure or documented contraindications and could not be initially prescribed by a general practitioner or a neurologist [37, 38]. A similar policy remains in place in Latvia, where general practitioners cannot reimburse DOACs unless the patient has a CHADS₂ – VASc score ≥ 4 and a contraindication to warfarin [39]. Although DOACs are relatively accessible for secondary stroke prevention in Latvia, access remains limited for primary stroke prevention.

However, this does not seem to apply to Estonia, where DOACs are reimbursed for more than 75% of the cost and could be prescribed by any physician for patients with AF. Their significantly higher median age could partly explain the higher AF prevalence in the Estonian patient cohort, and nonmodifiable factors associated with the highest weight on the risk of AF occurrence [40]. Although a patient's personal decision to deliberately discontinue anticoagulants in asymptomatic AF or currently normal rhythm, as well as differences in access to primary care due to insufficient funding, may further help explain the findings [41]. Nevertheless, despite having the highest AF prevalence, Estonian stroke patients with previously known AF were significantly more adherent to the use of anticoagulant treatment.

Our data also show that Latvia had significantly lower recanalization therapy rates among the Baltic states, both for IVT and EVT, despite having a significantly shorter door-to-groin time. We contemplate that this could be due to its stroke network covering its population distribution less efficiently, as only two CSCs provide 24/7 EVT in Latvia, which corresponds to the significantly longer onset-to-door intervals. The shortest

door-to-groin times can be explained by the fact that most EVTs are performed in a single CSC in Latvia, where patients are drip-and-shipped directly to EVT. All CSCs are prenotified about incoming EVT candidates.

Recanalization therapy rates have previously been shown to vary across different regions and times [11, 16, 42, 43]. Since regaining independence starting with 1990, the three Baltic states have been following a rather similar pathway of socioeconomic development, undergoing a period of rapid economic growth, reforming their healthcare, education, and other systems, in 2004 together joining the EU, the North Atlantic Treaty Organization (NATO), and later the Organization for Economic Cooperation and Development (OECD) [12]. Therefore, socioeconomic development alone could not account for differences in recanalization therapy rates, and other factors may have played a role.

As there are no guidelines for the universal use of computed tomography angiography (CTA) in acute stroke patients, there is a sizeable interhospital protocol variation in each of the Baltic states: Some stroke-ready hospitals perform CTA for all acute ischemic stroke patients, whereas others only in case of a suspected large vessel occlusion or lack this diagnostic functionality at all. Together with the differences in geographical stroke network distribution, this may be one of the factors contributing to the significant difference in lower EVT availability in Latvia.

Finally, we found that only 2.7% of stroke patients in Latvia were transferred to a rehabilitation center, whereas 69.7% of Latvian stroke patients were discharged home. This might be because there is a severe shortage of rehabilitation centers providing

TABLE 2 | Recanalization therapy rates and timeliness metrics.

	Lithuania (<i>n</i> = 479)		Latvia (<i>n</i> = 294)		Estonia (<i>n</i> = 124)		<i>p</i> value
Racanalization therapy, <i>n</i> (%)	186	(38.8)	67	(22.8)	61	(49.2)	< 0.001
Intravenous thrombolysis (IVT)	119	(24.8)	62	(21.1)	55	(44.4)	< 0.001
Alteplase	119	(100)	54	(87.1)	55	(100)	< 0.001
Tenecteplase	0		8	(12.9)	0		< 0.001
Endovascular treatment (EVT)	85	(17.7)	15	(5.1)	15	(12.1)	< 0.001
IVT and EVT	18	(3.8)	10	(3.4)	9	(7.3)	0.162
MTICI score mTICI ≥ 2b, <i>n</i> (%)	62	(83.8)	13	(86.7)	11	(73.3)	0.705
Decompressive craniectomy	5	(1.3)	0		1	(1.1)	0.132
Imaging within 60 min of admission, <i>n</i> (%)	391	(94.7)	186	(66.7)	82	(74.5)	< 0.001
Angiography (CTA or MRA), <i>n</i> (%)	262	(60.8)	119	(40.9)	109	(87.9)	< 0.001
Median timeliness metrics, min (IQR)							
Onset-to-door time	138	(76–394)	161.5	(97–575)	113	(63–302)	0.054
≤ 60 min, <i>n</i> (%)	24	(14.2)	17	(8.7)	15	(23.1)	0.010
≤ 270 min, <i>n</i> (%)	117	(69.2)	124	(63.3)	46	(70.8)	0.365
≤ 540 min, <i>n</i> (%)	132	(78.1)	146	(74.5)	53	(81.5)	0.125
≤ 1440 min, <i>n</i> (%)	156	(92.3)	181	(92.3)	58	(89.2)	0.702
> 1440 min, <i>n</i> (%)	13	(7.7)	15	(7.7)	7	(10.8)	0.702
Unknown (including wake-up strokes)	275	(61.9)	93	(32.2)	59	(52.2)	< 0.001
Onset-to-treatment time	165	(106–250)	151.5	(111–223)	116	(85–203)	0.093
Door-to-imaging time	19	(11–38) ^a	43	(19.5–79) ^b	24	(9–80) ^c	< 0.001
Door-to-needle time (for IVT)	27	(20–52)	38	(23–62)	33	(18–52)	0.120

(Continues)

TABLE 2 | (CONTINUED)

	Lithuania (<i>n</i> = 479)		Latvia (<i>n</i> = 294)		Estonia (<i>n</i> = 124)		<i>p</i> value
≤ 270 min, <i>n</i> (%)	119	(100)	58	(93.5)	53	(98.1)	0.010
270–540 min, <i>n</i> (%)	0		4	(6.5)	1	(1.9)	0.010
Door-to-groin time (for EVT)	102	(80–135)	61	(39–100)	84	(69– 103)	0.004
Treatment place, <i>n</i> (%)							<0.001
Comprehensive stroke center	394	(82.2)	162	(55.1)	84	(67.7)	
Primary stroke center	85	(17.8)	132	(44.9)	40	(32.3)	

Note: Bold values denote statistically significant results ($p < 0.05$), as stated in Methods Section 2.4.

Abbreviations: CTA, computed tomography angiography; EVT, endovascular treatment; IQR, interquartile range; IVT, intravenous thrombolysis; MRA, magnetic resonance angiography; mTICI, modified treatment in cerebral infarction.

^a*n* = 405.

^b*n* = 279.

^c*n* = 117.

TABLE 3 | Length of stay and discharge destinations.

	Lithuania (<i>n</i> = 479)		Latvia (<i>n</i> = 294)		Estonia (<i>n</i> = 124)		<i>p</i> value
Length of stay, median (IQR)	8	(6–12)	8	(6–11)	5	(3–8)	<0.001
Discharge destination, <i>n</i> (%)							<0.001
Home	148	(30.9)	205	(69.7)	57	(46.0)	<0.001
Rehabilitation	146	(30.5)	8	(2.7)	25	(20.2)	<0.001
Another department	31	(6.5)	4	(1.4)	11	(8.9)	<0.001
Postcare bed	24	(5.0)	30	(10.2)	9	(7.3)	0.023
Social care facility	55	(11.5)	12	(4.1)	8	(6.5)	0.001
Other (inhospital)	13	(2.7)	3	(1.0)	7	(5.6)	0.025
Death	62	(12.9)	32	(10.9)	7	(5.6)	0.070

Note: Bold values denote statistically significant results ($p < 0.05$), as stated in Methods Section 2.4.

Abbreviation: IQR, interquartile range.

state-funded stroke inpatient rehabilitation in Latvia. In fact, there is only one national center for rehabilitation, although the regional hospitals have some subacute rehabilitation beds available. Therefore, most patients are discharged home and have to wait up to 3 months for the state-funded rehabilitation. In the meantime, outpatient rehabilitation or rehabilitation at the patient's home could be provided.

In contrast, Lithuania and Estonia offer structured, fully state-funded rehabilitation services covered by the national insurance system. Stroke patients in Lithuania can receive inpatient rehabilitation for 18–54 days, depending on functional impairment (assessed by the Barthel index and cognitive tests). Outpatient rehabilitation includes up to 20 therapy sessions, and home-based rehabilitation, available twice per year, consists of 10 visits per course [44].

Looking ahead, the validity and comparability of Baltic stroke data could be strengthened by a coordinated, region-wide quality-monitoring program that adopts a shared key performance indicator set with harmonized operational definitions, standardizes use of a common data dictionary with structured training for clinicians and data-entry staff, and implements routine linkage of registry records to National Health Insurance Fund datasets and mortality registries to improve case ascertainment and follow-up [15]. To move beyond restricted data collection windows and reduce manual workload, an automatically generated dataset capable of feeding the RES-Q registry via an application programming interface (API) is being developed at Vilnius University Hospital [45]. Although cross-country deployment may not yet be feasible given substantial heterogeneity in hospital information systems and electronic health records, countries without continuous reporting could implement rolling

quarterly sampling with documented adjustment weights, validated against national administrative data [46]. In parallel, targeted strategies to align regional practice with the SAP-E 2018–2030 should guide indicator selection, target-setting, and audit-and-feedback cycles. Collectively, these measures would reduce the risk of selection bias, enhance external validity, and support targeted, region-wide quality improvement in stroke care, aimed at meeting SAP-E benchmarks.

Our research has several strengths. Importantly, the study established a cross-national quality-monitoring baseline spanning nearly all PSCs and CSCs in the Baltics, creating the preconditions for ongoing audit and feedback. Second, almost all PSCs and CSCs in Lithuania, Latvia, and Estonia participated in this study, ensuring a dataset accurately reflecting the national stroke care landscapes. Moreover, the results of this study are valuable for other regions, as it attempts to explain the varying stroke care strategies in a similar geographical and cultural setting. It sets a foundation for oriented improvements in stroke care and policy development across the Baltic region and beyond. It puts the numbers in context between three countries of comparable size and culturally and sociodemographically similar settings.

The study has several limitations. First, the study has a cross-sectional design at a single time point. As a result, it does not account for the natural yearly seasonal variability in factors such as stroke incidence, fluctuations in healthcare resources, such as increased strain on EMS, viral epidemics (COVID-19 and winter influenza), and other temporal factors that may affect the availability and quality of care for stroke patients. Nevertheless, since the same 3 months were analyzed in all three Baltic states, we believe the results are still well comparable between countries, which was our primary goal. In addition, a small sample size rendered the study underpowered to detect small-to-moderate effects, increasing the risk of Type II error. Third, several lower volume stroke centers reported fewer monthly cases than expected. This inconsistency indicates incomplete case capture and could have introduced a selection bias. Nevertheless, the results are in line with the National Health Insurance Fund data, which include comprehensive country information for the entire calendar year, making a substantial impact on the study's conclusions unlikely [47]. Fourth, our analysis only included stroke patients who were treated in stroke-ready hospitals. However, some patients were also treated in general hospitals, which are not categorized as PSCs or CSCs. These patients were not included in the dataset, potentially limiting the full representativeness of national stroke care pathways. Fifth, although the RES-Q data dictionary provides clear definitions for each variable, clinicians and data-entry staff may not have interpreted definitions of risk factors, discharge destinations, and other variables uniformly, potentially introducing misclassification bias—a common limitation of registry-based studies. In addition, two PSCs in Lithuania and one PSC in Estonia did not participate in the RES-Q registry during the study period. Thus, there is a relatively higher proportion of patients from CSCs in Lithuania than in Estonia and Latvia. However, these two hospitals handled relatively low patient volumes, so their exclusion is unlikely to have significantly biased the national picture. Finally, as is common in multicenter registry-based analyses, missing data was unlikely to be completely at random, particularly for key

variables such as baseline NIHSS scores and onset-to-door time. The use of an available-case analysis, while retaining a larger sample size, may introduce selection bias and reduce statistical power. Missing data were not imputed in the primary analyses; however, to improve transparency, we explicitly report the number of available data for variables with > 5% of missing values in the respective Tables of the Results section.

5 | Conclusions

This first comprehensive comparison of stroke care in the Baltic states highlights a high AF burden and significant disparities in recanalization therapy and poststroke rehabilitation pathways. Targeted strategies are required to align regional practices with the SAP-E 2018–2030. Further studies should investigate the reasons behind these intercountry differences and provide an overview of the stroke care network development dynamics in the Baltic states.

Author Contributions

Rytis Masiliūnas: conceptualization, methodology, writing—original draft, formal analysis, data curation, investigation, validation, and supervision. **Aurelija Daškevičiūtė:** writing—original draft and writing—review and editing. **Kristaps Jurjāns, Janika Kōrv, Riina Vibo, Saulius Taroza, Vaidotas Gudžiūnas, Paulius Puzinas, Erika Galvanauskaitė, and Gintarė Paulėkienė:** resources, data curation, and writing—review and editing. **Vaidas Matijošaitis, Aleksandras Vilionskis, Agnete Teivāne, Guntis Karelis, Katrin Gross-Paju, Katrin Sikk, Inga Samariūtē, and Katrin Antsov:** resources and writing—review and editing. **Arta Grosmane, Evija Miglāne, and Dalius Jatužis, and Robert Mikulik:** writing—review and editing. **Vitalija Šumskienė:** writing—original draft and data curation. **Edgaras Zaboras:** writing—original draft, formal analysis, data curation, and visualization. **Antanas Vaitkus:** conceptualization, methodology, writing—original draft, validation, and supervision.

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Ethics Statement

The Lithuanian Biomedical Ethics Committee approved the study protocol (Protocol Code L-22-08/1-9) and complied with STROBE guidelines for observational research.

Consent

Written informed consent for participation and publication was obtained from all patients or their legal representatives prior to enrollment.

Conflicts of Interest

The authors declare conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section. **Supporting Information 1.** File S1: STROBE checklist. The completed Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) checklist, detailing adherence to recommended reporting standards for observational studies, is available as a Supporting Information. **Supporting Information 2.** Table S1: List of stroke-ready hospitals in the Baltic states. All primary and comprehensive stroke centers (PSCs and CSCs) in the Baltic states,

including those participating in the RES-Q data collection during Q1 2022. **Supporting Information 3.** Figure S1: Antiplatelet therapy use before stroke onset among patients without known atrial fibrillation. Country-level comparison of antiplatelet use prior to the index ischemic stroke.