



# Predictors of spontaneous intracerebral hemorrhage mortality: a community-based study in Brno, Czech Republic

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## Abstract

**Background and objective** Intracerebral hemorrhage (ICH) is a serious medical condition with high mortality. However, factors leading to long-term mortality after ICH are largely unclear. The aim of this community-based study is to assess predictors of long-term mortality after spontaneous ICH.

**Methods** We identified all patients admitted with spontaneous ICH to hospitals with a certified stroke unit in Brno, the second largest city in the Czech Republic (CR), in 2011, the year of the Czech Population and Housing Census. We reviewed their medical records for risk factors, radiographic parameters, and measures of post-stroke neurological deficit [National Institutes of Health Stroke Scale (NIHSS)]. Using the dates of death from the Czech National Mortality Register, we calculated mortality at 30 days, six months, one year, and three years after the ICH. Multivariate analysis with forward stepwise logistic regression was performed to determine independent predictors of mortality ( $p < 0.05$ ).

**Results** In 2011, 1086 patients with stroke were admitted to the four stroke-certified hospitals in Brno, CR. Of these, 134 had spontaneous ICH, with complete data available in 93 of them entering the final analysis. The mortality at 30 days, 6 months, 1 year, and 3 years post-ICH was 34%, 47%, 51%, and 63%, respectively. The mortality was highest in the first few days post-event, with 50% of patients dying in 255 days and average survival being  $884 \pm 90$  days. Both NIHSS and modified ICH (MICH) score showed to be strong and reliable predictors of short- as well as long-term mortality; the risk of death post-ICH increased with older age and size of ICH. Other risk factors contributing to higher, primarily shorter-term mortality included history of cardiac failure, myocardial infarction, or atrial fibrillation.

**Conclusions** In our community-based study, we found that severity of neurological deficit at admission (NIHSS), combined with age and size of ICH, well predicted short- as well as long-term mortality after spontaneous ICH. A history of cardiac failure, myocardial infarction, or atrial fibrillation at presentation were also predictors of mortality, underscoring the need for optimal cardiac management in patients with ICH.

**Keywords** Czech Republic · Intracerebral hemorrhage · Mortality · Community-based study

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## Introduction

Despite advances in treatment and diagnosis, intracerebral hemorrhage (ICH) remains a serious medical condition with one month case fatality rates as high as 40% [1], and survival rates at one year and five years of 46% and 21%, respectively [2]. Incidence of ICH has been reported to be 24.6 per 100,000, and to increase significantly with age, with patients 85 years and older having a nearly ten-fold higher annual risk of developing ICH than those 45–54 years old [1, 3]. Both the incidence and early case fatality have remained high and have not decreased significantly between 1980 and 2008 [1]. The morbidity of ICH is also high, with only 12–39% of patients achieving long-term functional independence [1]. ICH thus represents a growing public health challenge and financial burden, especially in countries with aging populations.

There is considerable variability in published data regarding the predictors of mortality following ICH. Moreover, data on long-term prognostic factors are limited. In this study, we explore short- and long-term predictors of mortality following ICH in patients hospitalized for ICH in Brno, Czech Republic (CR).

## Methods

### Study type and population

For this study, data from two Czech national administrative databases were used—the National Register of Hospitalized Patients (NRHOSP) and the Czech National Mortality Registry (CNMR). Both databases have been described previously [4, 5]. In short, in the NRHOSP data about all hospital admissions in the Czech Republic are being

prospectively collected, the database has been previously validated the accuracy of the diagnostic codes for different stroke types. The CNMR collects information regarding all deaths in the Czech Republic [5].

For this community-based study, we searched the NRHOSP for all patients with discharge diagnosis of I61 [spontaneous (non-traumatic) ICH [International Classification of Diseases, Tenth Revision (ICD-10) code I61] admitted to any of the 4 hospitals with a certified stroke unit in Brno, Czech Republic (Hospital of the Merciful Brothers, Military Hospital Brno, St. Anne's University Hospital, and the University Hospital Brno) between January 1, 2011, and December 31, 2011. All patients with a suspected stroke are required to be transported to a hospital with a certified stroke unit as per the guidelines applicable in the whole Czech Republic [6]. The year 2011 was selected due to the availability of accurate demographic data from the 2011 Czech Population and Housing Census; the population of the city of Brno, our catchment area, was 385,913 people that year. For each patient identified, we requested his or her complete discharge summary from the admitting hospital. The methodology of patient selection, case ascertainment, and clinical data collection in this study was described previously [7, 8]. In short, two neurologists independently reviewed the discharge summaries, and verified the discharge diagnosis of ICH using the standard WHO definition.

To identify the patients who died, regardless of cause, following a diagnosis of IS and to calculate all-cause mortality rates, we linked the data from the hospitalization registry (NRHOSP) with the data from the mortality registry (CNMR) and calculated 1-days, 6-months, 1-year, and 3-year all-cause mortality rates [5]. The exact cause of death was not accounted of in our analysis.

### Clinical and radiological data collection

In summary, 16 clinical variables plus 15 radiological parameters were collected. Patients' discharge summaries were reviewed, and risk factors and other relevant clinical variables were recorded. Functional outcome and severity of stroke were assessed by the National Institutes of Health Stroke Scale (NIHSS) and modified Rankin Scale (mRS) at both admission and discharge, as well as the pre-admission mRS to detect any baseline impairment.

Following radiologic parameters were obtained from the initial CT scans: volume of ICH and absolute/relative perihematomal edema volume (both measured by the ABC/2 method)[9–11], volume of intraventricular extension of ICH[11] and spontaneous intraventricular hemorrhage (IVH) volume[12], total volume of ICH (TV) [12], midline shift [11], hematoma location [11, 13], ventricular compression [11], presence of sulcal and basal cistern effacement

**Table 1** Mortality after ICH

Percentiles of deceased (%)	Days post-event
10	2
20	6
25	9
30	15
40	63
50	255
60	1008
70	1998
75	2060
80	2105
90	2246

Table 2 Univariate analysis

Variable	30-day mortality			6-month mortality			1-year mortality			3-year mortality		
	Survived (76 patients)	Deceased (39 patients)	<i>p</i> value	Survived (61 patients)	Deceased (54 patients)	<i>p</i> value	Survived (56 patients)	Deceased (59 patients)	<i>p</i> value	Survived (43 patients)	Deceased (72 patients)	<i>p</i> value
<i>A. Descriptive statistics</i>												
NIHSS at admission	10.12±9.09 (1.00; 33.50)	24.10±10.54 (9.80;35.20)	<0.01	8.72±7.94 (1.00; 22.00)	21.80±11.31 (4.65;35.70)	<0.01	8.48±8.20 (0.75; 22.50)	20.92±11.24 (4.90;35.20)	<0.01	8.12±7.64 (0.10; 18.00)	18.89±11.80 (1.55;35.00)	<0.01
NIHSS at discharge	7.42±8.91 (0.00; 24.75)	40.72±4.03 (35.00;42.00)	<0.01	5.21±5.37 (0.00; 15.00)	33.96±13.56 (3.00;42.00)	<0.01	4.84±5.27 (0.00; 14.75)	31.88±14.74 (3.00;42.00)	<0.01	5.12±5.39 (0.00; 16.70)	26.83±17.29 (0.00;42.00)	<0.01
Prehospitalization mRS	0.32±0.96 (0.00; 2.00)	0.87±1.30 (0.00; 3.10)	<0.01	0.30±1.01 (0.00; 2.00)	0.74±1.18 (0.00; 3.00)	<0.01	0.20±0.80 (0.00; 1.00)	0.80±1.28 (0.00; 3.10)	<0.01	0.26±0.90 (0.00; 1.00)	0.65±1.20 (0.00; 3.00)	0.02
Epilepsy	5.00 (6.58%)	3.00 (7.69%)	>0.99	4.00 (6.56%)	4.00 (7.41%)	>0.99	3.00 (5.36%)	5.00 (8.47%)	0.71	2.00 (4.65%)	6.00 (8.33%)	0.70
ICH volume	13.99±16.33 (0.00; 46.19)	36.08±33.48 (4.55;96.55)	<0.01	14.69±17.60 (0.06; 46.73)	28.82±30.72 (1.85;92.53)	<0.01	13.42±16.13 (0.02; 45.74)	29.06±30.44 (1.09;90.82)	<0.01	13.27±17.22 (0.00; 46.34)	27.23±29.07 (0.94;86.85)	<0.01
IVHS	3.89±6.26 (0.00; 17.95)	5.85±5.78 (0.00; 15.20)	0.01	2.83±5.30 (0.00; 14.00)	6.27±6.48 (0.00; 17.65)	<0.01	3.02±5.43 (0.00; 14.00)	5.90±6.45 (0.00; 17.50)	<0.01	3.22±5.82 (0.00; 14.80)	5.43±6.23 (0.00; 17.15)	0.01
IVH volume	5.56±11.70 (0.00; 36.27)	6.56±10.93 (0.00; 21.85)	0.01	3.44±8.37 (0.00; 16.44)	8.32±13.37 (0.00; 34.28)	<0.01	3.68±8.61 (0.00; 16.44)	7.83±13.11 (0.00; 33.28)	<0.01	4.17±9.31 (0.00; 20.48)	7.01±12.49 (0.00; 30.96)	0.01
TV	19.74±20.37 (0.58; 52.17)	42.64±37.97 (5.65;104.23)	<0.01	18.21±20.91 (0.47; 50.96)	37.31±34.14 (5.38; 100.42)	<0.01	17.19±20.14 (0.63; 47.87)	37.04±33.70 (5.32; 100.24)	<0.01	17.56±21.71 (0.53; 48.97)	34.37±32.47 (4.04; 99.81)	<0.01
MLS	2.93±3.73 (0.00; 9.07)	6.52±6.87 (0.00; 20.86)	0.02	2.96±3.91 (0.00; 8.97)	5.38±6.18 (0.00; 19.10)	0.07	2.91±4.04 (0.00; 9.24)	5.27±6.50 (0.00; 18.50)	0.05	2.88±4.19 (0.00; 17.10)	5.01±5.77 (0.00; 17.10)	0.06
Largest diameter of ICH	34.56±18.89 (0.52; 65.66)	57.76±22.32 (28.36; 94.89)	<0.01	34.24±19.49 (3.12; 65.45)	50.82±23.20 (19.44; 93.44)	<0.01	33.85±19.19 (1.83; 64.84)	50.18±23.30 (14.35; 93.20)	<0.01	32.82±19.74 (0.00; 61.14)	48.86±22.73 (15.86; 92.64)	<0.01
Foramen magnum herniation	7.00 (11.29%)	4.00 (12.12%)	>0.99	5.00 (10.64%)	6.00 (12.50%)	>0.99	5.00 (11.36%)	6.00 (11.76%)	>0.99	4.00 (10.81%)	7.00 (12.07%)	>0.99
Tentorial herniation	1.00 (1.61%)	0.00 (0.00%)	>0.99	0.00 (0.00%)	1.00 (2.08%)	>0.99	0.00 (0.00%)	1.00 (1.96%)	>0.99	0.00 (0.00%)	1.00 (1.72%)	>0.99
Ventricular effacement	30.00 (48.39%)	27.00 (81.82%)	<0.01	23.00 (48.94%)	34.00 (70.83%)	0.03	21.00 (47.73%)	36.00 (70.59%)	0.03	15.00 (40.54%)	42.00 (72.41%)	<0.01
Sulcal effacement	25.00 (40.32%)	25.00 (75.76%)	<0.01	20.00 (42.55%)	30.00 (62.50%)	0.06	18.00 (40.91%)	32.00 (62.75%)	0.04	14.00 (37.84%)	36.00 (62.07%)	0.04
Cisternal effacement	4.00 (6.45%)	13.00 (39.39%)	<0.01	1.00 (2.13%)	16.00 (33.33%)	<0.01	1.00 (2.27%)	16.00 (31.37%)	<0.01	1.00 (2.70%)	16.00 (27.59%)	<0.01
Hydrocephalus score	0.79±2.11 (0.00; 4.00)	1.64±3.25 (0.00; 9.00)	0.24	0.32±1.30 (0.00; 2.40)	1.83±3.24 (0.00; 9.00)	<0.01	0.34±1.35 (0.00; 2.70)	1.73±3.17 (0.00; 9.00)	0.01	0.41±1.46 (0.00; 3.00)	1.52±3.02 (0.00; 9.00)	0.04
Perihematomal edema volume	25.05±25.99 (1.23; 69.80)	64.32±52.66 (14.45; 164.09)	<0.01	26.18±28.30 (0.32; 69.88)	51.53±49.00 (6.13; 158.09)	<0.01	24.77±27.22 (0.13; 69.78)	51.21±48.26 (4.21; 157.82)	<0.01	23.81±28.59 (0.00; 69.83)	48.57±46.15 (3.77; 157.18)	<0.01
Relative perihematomal edema volume	11.06±10.79 (0.83; 30.21)	28.24±23.23 (6.64; 75.29)	<0.01	11.49±11.66 (0.22; 30.47)	22.71±21.56 (3.26; 69.88)	<0.01	11.35±11.81 (0.09; 30.53)	22.15±21.13 (2.36; 68.70)	<0.01	10.53±12.02 (0.00; 30.94)	21.34±20.17 (2.25; 65.96)	<0.01
Age at stroke	67.93±14.62 (40.59; 87.55)	75.03±12.08 (55.19; 90.19)	0.02	66.45±15.13 (38.85; 87.54)	74.73±11.65 (56.35; 89.63)	<0.01	65.92±15.42 (38.58; 86.14)	74.53±11.51 (56.61; 89.50)	<0.01	63.99±15.38 (37.89; 87.35)	74.13±11.98 (53.46; 89.03)	<0.01
History of cerebral ischemia	6.00 (8.11%)	7.00 (19.44%)	0.12	6.00 (10.00%)	7.00 (14.00%)	0.58	5.00 (9.09%)	8.00 (14.55%)	0.56	3.00 (6.98%)	10.00 (14.93%)	0.24
History of ICH	3.00 (4.00%)	1.00 (2.78%)	>0.99	2.00 (3.28%)	2.00 (4.00%)	>0.99	2.00 (3.57%)	2.00 (3.64%)	>0.99	2.00 (4.65%)	2.00 (2.94%)	>0.99
History of SAH	1.00 (1.32%)	2.00 (5.41%)	0.24	1.00 (1.64%)	2.00 (3.85%)	0.60	1.00 (1.79%)	2.00 (3.51%)	>0.99	1.00 (2.33%)	2.00 (2.86%)	>0.99
Antiplatelet medication	18.00 (25.35%)	11.00 (34.38%)	0.46	16.00 (27.12%)	13.00 (29.55%)	0.82	14.00 (25.93%)	15.00 (30.61%)	0.67	8.00 (19.05%)	21.00 (34.43%)	0.12
History of cardiac failure	1.00 (1.32%)	6.00 (15.38%)	0.01	1.00 (1.64%)	6.00 (11.11%)	0.05	1.00 (1.79%)	6.00 (10.17%)	0.12	1.00 (2.33%)	6.00 (8.33%)	0.25

Table 2 (continued)

Variable	30-day mortality			6-month mortality			1-year mortality			3-year mortality		
	Survived (76 patients)	Deceased (39 patients)	p value	Survived (61 patients)	Deceased (54 patients)	p value	Survived (56 patients)	Deceased (59 patients)	p value	Survived (43 patients)	Deceased (72 patients)	p value
History of myocardial infarction	12.00 (15.79%)	12.00 (30.77%)	0.08	8.00 (13.11%)	16.00 (29.63%)	0.04	8.00 (14.29%)	16.00 (27.12%)	0.11	7.00 (16.28%)	17.00 (23.61%)	0.49
History of atrial fibrillation	14.00 (18.42%)	13.00 (33.33%)	0.10	8.00 (13.11%)	19.00 (35.19%)	0.01	7.00 (12.50%)	20.00 (33.90%)	0.01	7.00 (16.28%)	20.00 (27.78%)	0.18
History of hypertension	67.00 (88.16%)	31.00 (79.49%)	0.28	53.00 (86.89%)	45.00 (83.33%)	0.59	49.00 (87.50%)	49.00 (83.05%)	0.60	37.00 (86.05%)	61.00 (84.72%)	>0.99
History of diabetes mellitus	15.00 (19.74%)	13.00 (33.33%)	0.11	11.00 (18.03%)	17.00 (31.48%)	0.13	10.00 (17.86%)	18.00 (30.51%)	0.13	7.00 (16.28%)	21.00 (29.17%)	0.17
Body mass index	27.51 ± 5.17 (22.49; 36.26)	26.22 ± 5.08 (18.17; 32.92)	0.66	27.83 ± 5.33 (22.63; 36.78)	26.05 ± 4.71 (18.37; 33.03)	0.32	27.93 ± 5.44 (22.61; 36.95)	26.06 ± 4.54 (18.56; 33.01)	0.31	27.25 ± 4.22 (22.80; 36.04)	27.09 ± 5.88 (19.23; 33.81)	0.69
MICH score	1.50 ± 0.97 (0.00; 3.00)	3.27 ± 1.31 (0.60; 5.00)	<0.01	1.33 ± 0.94 (0.00; 2.00)	2.91 ± 1.30 (1.00; 5.00)	<0.01	1.28 ± 0.96 (0.00; 2.00)	2.86 ± 1.28 (1.00; 5.00)	<0.01	1.25 ± 0.87 (0.00; 2.00)	2.68 ± 1.36 (0.00; 5.00)	<0.01
Primary location = supratentorial	54.00 (87.10%)	26.00 (78.79%)	0.37	40.00 (85.11%)	40.00 (83.33%)	>0.99	37.00 (84.09%)	43.00 (84.31%)	>0.99	31.00 (83.78%)	49.00 (84.48%)	>0.99
Nontraumatic ICH in hemisphere, subcortical (I61-0, referral)	20 (26.32%)	10 (25.64%)	0.63	17 (27.87%)	13 (24.07%)	0.85	17 (30.36%)	13 (22.03%)	0.30	10 (23.26%)	20 (27.78%)	0.46
Nontraumatic ICH in hemisphere, cortical (I61-1)	15 (19.74%)	5 (12.82%)	–	12 (19.67%)	8 (14.81%)	–	11 (19.64%)	9 (15.25%)	–	9 (20.93%)	11 (15.28%)	–
Nontraumatic ICH in hemisphere, unspecified (I61-2)	19 (25%)	8 (20.51%)	–	13 (21.31%)	14 (25.93%)	–	12 (21.43%)	15 (25.42%)	–	9 (20.93%)	18 (25%)	–
Nontraumatic ICH in brain stem (I61-3)	2 (2.63%)	5 (12.82%)	–	2 (3.28%)	5 (9.26%)	–	1 (1.79%)	6 (10.17%)	–	1 (2.33%)	6 (8.33%)	–
Nontraumatic ICH in cerebellum (I61-4)	7 (9.21%)	5 (12.82%)	–	5 (8.2%)	7 (12.96%)	–	3 (5.36%)	9 (15.25%)	–	3 (6.98%)	9 (12.5%)	–
Nontraumatic ICH intraventricular (I61-5)	3 (3.95%)	1 (2.56%)	–	3 (4.92%)	1 (1.85%)	–	3 (5.36%)	1 (1.69%)	–	3 (6.98%)	1 (1.39%)	–
Nontraumatic ICH, multiple localized (I61-6)	2 (2.63%)	1 (2.56%)	–	2 (3.28%)	1 (1.85%)	–	2 (3.57%)	1 (1.69%)	–	2 (4.65%)	1 (1.39%)	–
Other nontraumatic ICH (I61-8)	1 (1.32%)	1 (2.56%)	–	1 (1.64%)	1 (1.85%)	–	1 (1.79%)	1 (1.69%)	–	1 (2.33%)	1 (1.39%)	–
Nontraumatic ICH, unspecified (I61-9)	7 (9.21%)	3 (7.69%)	–	6 (9.84%)	4 (7.41%)	–	6 (10.71%)	4 (6.78%)	–	5 (11.63%)	5 (6.94%)	–
MICH score (category 0–1)	30 (50%)	4 (12.12%)	<0.01	26 (56.52%)	8 (17.02%)	<0.01	26 (60.47%)	8 (16%)	<0.01	22 (61.11%)	12 (21.05%)	<0.01
MICH score (category 2–3)	28 (46.67%)	14 (42.42%)	–	18 (39.13%)	24 (51.06%)	–	15 (34.88%)	27 (54%)	–	13 (36.11%)	29 (50.88%)	–
MICH score (category 4–6)	2 (3.33%)	15 (45.45%)	–	2 (4.35%)	15 (31.91%)	–	2 (4.65%)	15 (30%)	–	1 (2.78%)	16 (28.07%)	–

Table 2 (continued)

Variable	30-day mortality			6-month mortality			1-year mortality			3-year mortality		
	Survived (76 patients)	Deceased (39 patients)	p value	Survived (61 patients)	Deceased (54 patients)	p value	Survived (56 patients)	Deceased (59 patients)	p value	Survived (43 patients)	Deceased (72 patients)	p value
Prehospitalization mRS (category 0-1)	70 (92.11%)	29 (74.36%)	0.03	57 (93.44%)	42 (77.78%)	0.02	54 (96.43%)	45 (76.27%)	<0.01	41 (95.35%)	58 (80.56%)	0.05
Prehospitalization mRS (category 2-3)	4 (5.26%)	8 (20.51%)	-	2 (3.28%)	10 (18.52%)	-	1 (1.79%)	11 (18.64%)	-	1 (2.33%)	11 (15.28%)	-
Prehospitalization mRS (category 4-6)	2 (2.63%)	2 (5.13%)	-	2 (3.28%)	2 (3.7%)	-	1 (1.79%)	3 (5.08%)	-	1 (2.33%)	3 (4.17%)	-
NIHSS at admission (category 0-5)	33 (43.42%)	1 (2.56%)	<0.01	29 (47.54%)	5 (9.26%)	<0.01	29 (51.79%)	5 (8.47%)	<0.01	23 (53.49%)	11 (15.28%)	<0.01
NIHSS at admission (category 6-10)	11 (14.47%)	3 (7.69%)	-	10 (16.39%)	4 (7.41%)	-	8 (14.29%)	6 (10.17%)	-	5 (11.63%)	9 (12.5%)	-
NIHSS at admission (category 11-20)	25 (32.89%)	16 (41.03%)	-	18 (29.51%)	23 (42.59%)	-	15 (26.79%)	26 (44.07%)	-	13 (30.23%)	28 (38.89%)	-
NIHSS at admission (category 21-42)	7 (9.21%)	19 (48.72%)	-	4 (6.56%)	22 (40.74%)	-	4 (7.14%)	22 (37.29%)	-	2 (4.65%)	24 (33.33%)	-
NIHSS at discharge (category 0-5)	46 (60.53%)	0 (0%)	<0.01	41 (67.21%)	5 (9.26%)	<0.01	39 (69.64%)	7 (11.86%)	<0.01	30 (69.77%)	16 (22.22%)	<0.01
NIHSS at discharge (category 6-10)	11 (14.47%)	0 (0%)	-	9 (14.75%)	2 (3.7%)	-	9 (16.07%)	2 (3.39%)	-	6 (13.95%)	5 (6.94%)	-
NIHSS at discharge (category 11-20)	14 (18.42%)	1 (2.56%)	-	10 (16.39%)	5 (9.26%)	-	7 (12.5%)	8 (13.56%)	-	6 (13.95%)	9 (12.5%)	-
NIHSS at discharge (category 21-42)	5 (6.58%)	38 (97.44%)	-	1 (1.64%)	42 (77.78%)	-	1 (1.79%)	42 (71.19%)	-	1 (2.33%)	42 (58.33%)	-
Female sex	34 (44.74%)	21 (53.85%)	0.43	28 (45.9%)	27 (50%)	0.71	26 (46.43%)	29 (49.15%)	0.85	20 (46.51%)	35 (48.61%)	0.85
Male sex	42 (55.26%)	18 (46.15%)	-	33 (54.1%)	27 (50%)	-	30 (53.57%)	30 (50.85%)	-	23 (53.49%)	37 (51.39%)	-
	30-day mortality			6-month mortality			1-year mortality			3-year mortality		
Variable	OR (95% CI)		p value	OR (95% CI)		p value	OR (95% CI)		p value	OR (95% CI)		p value
<b>B. Generalized linear model</b>												
Nontraumatic ICH in hemisphere, subcortical (I61-0, reference value)	-	-	-	-	-	-	-	-	-	-	-	-
Nontraumatic ICH in hemisphere, cortical (I61-1)	0.67 (0.18;2.30)		0.53	0.87 (0.27;2.75)		0.82	1.07 (0.34;3.36)		0.91	0.61 (0.19;1.96)		0.41
Nontraumatic ICH in hemisphere, unspecified (I61-2)	0.84 (0.27;2.59)		0.76	1.41 (0.50;4.06)		0.52	1.64 (0.58;4.74)		0.36	1.00 (0.33;3.05)		>0.99
Nontraumatic ICH in brain stem (I61-3)	5.00 (0.90;39.48)		0.08	3.27 (0.60;25.47)		0.20	7.85 (1.15;158.06)		0.07	3.00 (0.43;60.75)		0.34

Table 2 (continued)

Variable	30-day mortality		6-month mortality		1-year mortality		3-year mortality	
	OR (95% CI)	p value	OR (95% CI)	p value	OR (95% CI)	p value	OR (95% CI)	p value
Nontraumatic ICH in cerebellum (I61-4)	1.43 (0.35;5.68)	0.61	1.83 (0.48;7.48)	0.38	3.92 (0.95;20.46)	0.07	1.50 (0.35;7.89)	0.60
Nontraumatic ICH intraventricular (I61-5)	0.67 (0.03;6.00)	0.74	0.44 (0.02;3.86)	0.49	0.44 (0.02;3.86)	0.49	0.17 (0.01;1.49)	0.14
Nontraumatic ICH, multiple localized (I61-6)	1.00 (0.04;11.71)	>0.99	0.65 (0.03;7.57)	0.74	0.65 (0.03;7.57)	0.74	0.25 (0.01;2.91)	0.28
Other nontraumatic ICH (I61-8)	2.00 (0.07;54.24)	0.64	1.31 (0.05;35.20)	0.85	1.31 (0.05;35.20)	0.85	0.50 (0.02;13.53)	0.64
Nontraumatic ICH, unspecified (I61-9)	0.86 (0.16;3.85)	0.85	0.87 (0.19;3.71)	0.85	0.87 (0.19;3.71)	0.85	0.50 (0.11;2.18)	0.35
Female sex (reference value)	-	-	-	-	-	-	-	-
Male sex	0.69 (0.32;1.50)	0.36	0.85 (0.41;1.77)	0.66	0.90 (0.43;1.87)	0.77	0.92 (0.43;1.96)	0.83
NIHSS at admission	1.13 (1.08;1.19)	<0.01	1.14 (1.09;1.21)	<0.01	1.14 (1.08;1.20)	<0.01	1.12 (1.07;1.18)	<0.01
NIHSS at discharge	1.29 (1.18;1.53)	<0.01	1.20 (1.13;1.30)	<0.01	1.19 (1.12;1.29)	<0.01	1.13 (1.08;1.20)	<0.01
Prehospitalization mRS	1.55 (1.10;2.32)	0.02	1.50 (1.04;2.31)	0.04	1.94 (1.25;3.50)	0.01	1.52 (1.01;2.62)	0.08
Epilepsy	1.18 (0.23;5.10)	0.82	1.14 (0.26;5.05)	0.86	1.64 (0.38;8.30)	0.52	1.86 (0.41;13.13)	0.46
ICH volume	1.04 (1.02;1.06)	<0.01	1.02 (1.01;1.05)	<0.01	1.03 (1.01;1.06)	0.01	1.03 (1.01;1.06)	0.02
IVHS	1.05 (0.98;1.13)	0.14	1.11 (1.03;1.20)	0.01	1.09 (1.01;1.18)	0.03	1.07 (0.99;1.16)	0.09
IVH volume	1.01 (0.97;1.04)	0.68	1.05 (1.00;1.10)	0.05	1.04 (1.00;1.09)	0.09	1.03 (0.99;1.08)	0.25
TV	1.03 (1.01;1.05)	<0.01	1.03 (1.01;1.05)	<0.01	1.03 (1.01;1.06)	<0.01	1.03 (1.01;1.05)	0.01
MLS	1.14 (1.05;1.26)	<0.01	1.10 (1.01;1.21)	<0.01	1.10 (1.01;1.22)	0.04	1.09 (1.00;1.22)	0.06
Largest diameter of ICH	1.06 (1.03;1.09)	<0.01	1.04 (1.02;1.06)	<0.01	1.04 (1.02;1.06)	<0.01	1.04 (1.02;1.06)	<0.01
Foramen magnum herniation	1.08 (0.27;3.90)	0.90	1.20 (0.34;4.45)	0.78	1.04 (0.29;3.86)	0.95	1.13 (0.32;4.60)	0.85
Tentorial herniation	0.00 (NA; > 10 000)	0.99	5.757,812.86 (<0.0005;NA)	0.99	5.066,875.32 (<0.0005;NA)	0.99	3.737,527.65 (<0.0005;NA)	0.99
Ventricular effacement	4.80 (1.83;14.34)	<0.01	2.53 (1.10;6.01)	<0.01	2.63 (1.14;6.22)	0.03	3.85 (1.63;9.43)	<0.01
Sulcal effacement	4.62 (1.86;12.50)	<0.01	2.25 (1.00;5.19)	<0.01	2.43 (1.07;5.65)	0.04	2.69 (1.16;6.41)	0.02
Cisternal effacement	9.43 (2.96;36.61)	<0.01	23.00 (4.36;425.56)	<0.01	19.66 (3.73;363.50)	0.01	13.71 (2.60;253.56)	0.01
Hydrocephalus score	1.13 (0.96;1.34)	0.14	1.41 (1.12;1.99)	0.02	1.36 (1.09;1.91)	0.03	1.27 (1.03;1.76)	0.06
Perihematomal edema volume	1.03 (1.01;1.04)	<0.01	1.02 (1.01;1.03)	<0.01	1.02 (1.01;1.04)	0.01	1.02 (1.01;1.04)	0.01
Relative perihematomal edema volume	1.07 (1.03;1.11)	<0.01	1.04 (1.02;1.08)	<0.01	1.04 (1.01;1.08)	0.01	1.05 (1.02;1.10)	0.01
Age at stroke	1.04 (1.01;1.08)	0.01	1.05 (1.02;1.08)	<0.01	1.05 (1.02;1.08)	<0.01	1.06 (1.03;1.09)	<0.01
History of cerebral ischemia	2.74 (0.84;9.19)	0.09	1.47 (0.46;4.86)	0.52	1.70 (0.53;5.98)	0.38	2.34 (0.67;10.92)	0.22
History of ICH	0.69 (0.03;5.58)	0.75	1.23 (0.14;10.55)	0.84	1.02 (0.12;8.74)	0.99	0.62 (0.07;5.34)	0.64
History of SAH	4.29 (0.40;94.05)	0.24	2.40 (0.22;52.53)	0.48	2.00 (0.19;43.77)	0.58	1.24 (0.12;27.06)	0.87
Antiplatelet medication	1.54 (0.61;3.80)	0.35	1.13 (0.47;2.68)	0.79	1.26 (0.53;3.00)	0.60	2.23 (0.90;5.95)	0.09
History of cardiac failure	13.64 (2.21;262.98)	0.02	7.50 (1.23;144.21)	0.07	6.23 (1.02;119.69)	0.10	3.82 (0.62;73.46)	0.22

Table 2 (continued)

Variable	30-day mortality		6-month mortality		1-year mortality		3-year mortality	
	OR (95% CI)	<i>p</i> value	OR (95% CI)	<i>p</i> value	OR (95% CI)	<i>p</i> value	OR (95% CI)	<i>p</i> value
History of myocardial infarction	2.37 (0.94;6.00)	0.07	2.79 (1.11;7.50)	0.03	2.23 (0.89;5.99)	0.10	1.59 (0.62;4.46)	0.35
History of atrial fibrillation	2.21 (0.91;5.39)	0.08	3.60 (1.46;9.56)	0.01	3.59 (1.43;9.95)	0.01	1.98 (0.78;5.49)	0.16
History of hypertension	0.52 (0.18;1.51)	0.22	0.76 (0.26;2.13)	0.59	0.70 (0.24;1.97)	0.50	0.90 (0.29;2.57)	0.85
History of diabetes mellitus	2.03 (0.84;4.89)	0.11	2.09 (0.88;5.10)	0.10	2.02 (0.85;5.02)	0.12	2.12 (0.84;5.86)	0.12
Body mass index	0.95 (0.82;1.07)	0.41	0.93 (0.81;1.04)	0.22	0.92 (0.81;1.03)	0.19	0.99 (0.89;1.11)	0.91
MICH score	3.84 (2.35;7.09)	<0.01	3.26 (2.08;5.63)	<0.01	3.28 (2.09;5.71)	<0.01	2.78 (1.82;4.65)	<0.01
NIHSS at admission (category 0–5, reference value)	–	–	–	–	–	–	–	–
NIHSS at admission (category 6–10)	9.00 (1.03;192.75)	0.07	2.32 (0.49;10.57)	0.27	4.35 (1.06;19.05)	0.04	3.76 (1.05;14.91)	0.05
NIHSS at admission (category 11–20)	21.12 (3.91;393.92)	<0.01	7.41 (2.54;25.31)	<0.01	10.05 (3.42;34.73)	<0.01	4.50 (1.74;12.34)	<0.01
NIHSS at admission (category 21–42)	89.57 (14.96;1751.21)	<0.01	31.90 (8.49;152.92)	<0.01	31.90 (8.49;152.92)	<0.01	25.09 (6.03;174.83)	<0.01
NIHSS at discharge (category 0–5, reference value)	–	–	–	–	–	–	–	–
NIHSS at discharge (category 6–10)	1.00 (<0.005; > 10 000)	>0.99	1.82 (0.23;10.08)	0.51	1.24 (0.17;6.24)	0.81	1.56 (0.40;6.00)	0.51
NIHSS at discharge (category 11–20)	61,038,244.98 (<0.005;NA)	>0.99	4.10 (0.97;17.63)	0.05	6.37 (1.78;24.45)	0.01	2.81 (0.86;9.78)	0.09
NIHSS at discharge (category 21–42)	6,494,469,266.33 (<0.005; > 10 000)	0.99	344.40 (56.97;6829.42)	<0.01	234.00 (40.93;4504.35)	<0.01	78.75 (14.94;1461.10)	<0.01
MICH score (category 0–1, reference value)	–	–	–	–	–	–	–	–
MICH score (category 2–3)	3.75 (1.18;14.48)	0.03	4.33 (1.64;12.35)	<0.01	5.85 (2.20;16.93)	<0.01	4.09 (1.60;11.02)	<0.01
MICH score (category 4–6)	56.25 (11.13;462.55)	<0.01	24.38 (5.44;177.89)	<0.01	24.38 (5.44;177.89)	<0.01	29.33 (5.04;562.80)	<0.01
NIHSS at discharge (categorical)	–	–	–	–	–	–	–	–
MICH score (categorical)	4.83 (1.41;19.27)	0.02	6.79 (1.68;45.67)	0.02	13.20 (2.43;245.90)	0.02	7.78 (1.43;144.90)	0.05
Prehospitalisation mRS (categorical)	2.41 (0.28;20.91)	0.39	1.36 (0.16;11.69)	0.77	3.60 (0.44;74.16)	0.28	2.12 (0.26;43.70)	0.52
Primary location = supratentorial	0.55 (0.18;1.72)	0.30	0.88 (0.28;2.66)	0.81	1.02 (0.33;3.10)	0.98	1.05 (0.32;3.21)	0.93

**Table 3** Multivariate analysis and predictors of mortality in Model A and Model B

30-day mortality			6-month mortality			1-year mortality			3-year mortality		
Predictor variable	OR (95% CI)	p value	Predictor variable	OR (95% CI)	p value	Predictor variable	OR (95% CI)	p value	Predictor variable	OR (95% CI)	p value
<i>Model A</i>											
NIHSS at admission	1.16 (1.08; 1.25)	<0.01	NIHSS at admission	1.16 (1.08; 1.26)	<0.01	NIHSS at admission	1.15 (1.08; 1.24)	<0.01	NIHSS at admission	1.11 (1.05; 1.19)	<0.01
Age at stroke	1.08 (1.03; 1.17)	0.01	Age at stroke	1.08 (1.03; 1.14)	<0.01	Age at stroke	1.08 (1.04; 1.15)	<0.01	Age at stroke	1.09 (1.04; 1.14)	<0.01
Largest diameter of ICH	1.07 (1.03; 1.12)	<0.01	Largest diameter of ICH	1.04 (1.01; 1.08)	0.03	Prehospitalization mRS	1.99 (1.06; 5.11)	0.07	Largest diameter of ICH	1.03 (1.00; 1.07)	0.06
History of cardiac failure	42.35 (2.45; 2064.42)	0.03	Hydrocephalus score	1.59 (1.09; 2.48)	0.03	Hydrocephalus score	1.37 (1.00; 2.02)	0.08			
			History of myocardial infarction	6.81 (1.43; 38.52)	0.02						
<i>Model cross-validation</i>											
Value $\pm$ SD	0.83 $\pm$ 0.13		Value $\pm$ SD	0.77 $\pm$ 0.13		Value $\pm$ SD	0.77 $\pm$ 0.12		Value $\pm$ SD	0.75 $\pm$ 0.12	
Observed accuracy	0.62 $\pm$ 0.27		Observed accuracy	0.53 $\pm$ 0.27		Observed accuracy	0.54 $\pm$ 0.25		Observed accuracy	0.47 $\pm$ 0.26	
Expected accuracy (kappa coefficient)			Expected accuracy (kappa coefficient)			Expected accuracy (kappa coefficient)			Expected accuracy (kappa coefficient)		
<i>Model B</i>											
MICH score	3.69 (2.19; 7.18)	<0.01	MICH score	3.02 (1.85; 5.49)	<0.01	MICH score	4.48 (2.56; 9.23)	<0.01	MICH score	2.40 (1.52; 4.14)	<0.01
History of cardiac failure	23.01 (2.06; 638.55)	0.02	Age at stroke	1.03 (0.99; 1.08)	0.11	History of atrial fibrillation	11.94 (2.81; 64.40)	<0.01	Age at stroke	1.06 (1.02; 1.11)	<0.01
Sulcal effacement	4.10 (1.20; 15.77)	0.03	Hydrocephalus score	1.27 (1.00; 1.80)	0.10				Ventricular effacement	2.93 (0.98; 9.23)	0.06
			History of myocardial infarction	3.46 (0.84; 15.62)	0.09						
<i>Model cross-validation</i>											
Value $\pm$ SD	0.83 $\pm$ 0.12		Value $\pm$ SD	0.74 $\pm$ 0.12		Value $\pm$ SD	0.77 $\pm$ 0.14		Value $\pm$ SD	0.74 $\pm$ 0.13	
Observed accuracy	0.61 $\pm$ 0.27		Observed accuracy	0.47 $\pm$ 0.24		Observed accuracy	0.54 $\pm$ 0.28		Observed accuracy	0.42 $\pm$ 0.29	
Expected accuracy (kappa coefficient)			Expected accuracy (kappa coefficient)			Expected accuracy (kappa coefficient)			Expected accuracy (kappa coefficient)		



[14], hydrocephalus score [14], and presence of foramen magnum herniation [15]. Finally, the modified ICH (MICH) score was calculated [16].

## Statistics

Associations between mortality and patient parameters were calculated in the univariate analysis for the individual time points (30 days, six months, one and three years). Significant variables then entered the multivariate analysis in two models based on their mutual noncollinearity (Model A with NIHSS at admission and Model B with MICH score as leading factors) in which forward stepwise logistic regression was performed to determine independent predictors of mortality. Data are presented as mean values accompanied by standard deviation (SD) or as odds ratios (OR) with 95% confidence intervals (CI), assuming normal approximation of the binominal distribution. A  $p$  value  $\leq 0.05$  was considered statistically significant. Additionally, in the multivariate analysis, receiver operating characteristic (ROC) curves with area under curve (AUC) values are used to describe the data. The results then underwent a tenfold cross-validation to check for their accuracy and standardized accuracy (coefficient kappa).

## Statement of ethics

This study was approved by the ethics committees of all participating hospitals (Hospital of the Merciful Brothers, Military Hospital Brno, St. Anne's University Hospital, and the University Hospital Brno) and by the ethics committee of the Institute of Health Information and Statistics of the CR. Informed consent requirement has been waived by the above ethics committees, as this is a retrospective medical record review study. This study conforms with the guidelines outlined in the Declaration of Helsinki.

## Results

In 2011, there were 1086 patients with stroke admitted to the four study hospitals in Brno, CR. Of these, 134 had spontaneous ICH, with available and complete data in 93 of them entering the final analysis (Table 1, Online Appendix). The mortality rate at 30 days, six months, one year, and three years post-ICH was 34%, 47%, 51%, and 63%, respectively. The mortality is highest in the first few days post-event, with 50% of patients dying in 255 days and average survival being  $884 \pm 90$  days (Table 1).

The associations between 16 clinical variables plus 15 radiological parameters and post-ICH mortality in the univariate analysis are summarized in Table 2. Results of the multivariate analysis are shown in Table 3 and Figs. 1, 2, 3.

Both NIHSS and MICH score showed to be strong and reliable predictors of short- as well as long-term mortality; the risk of death post-ICH increases with older age and size of ICH. Among the risk factors contributing to higher, primarily shorter-term mortality are also history of cardiac failure, myocardial infarction, or atrial fibrillation.

## Discussion

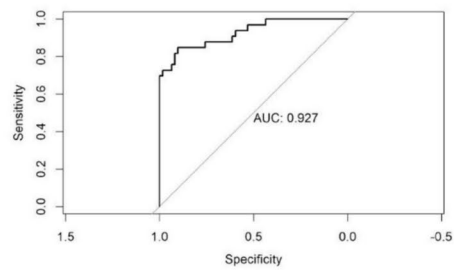
In this community-based study, we assessed ICH mortality and its predictors in a geographically defined area of the city of Brno, CR. Our study has two major findings. Firstly, mortality at 30 days, six months, one year, and three years was 34%, 47%, 51%, and 63%, respectively. Such mortality rates are similar to those reported in several meta-analyses [1, 2] and our previous data on hemorrhagic stroke mortality in the CR [5]. The current data suggests that ICH mortality in the CR, three decades after the end of communism, was comparable or lower than that reported from other developed countries. Also, it suggests the high quality of care of stroke patients in the CR, a post-communist country in Central Europe with relatively scant data on stroke epidemiology.

Secondly, we identified predictors of both short- and long-term mortality after spontaneous ICH. We found that a patient's functional neurological status, as assessed by the NIHSS at admission to hospital, was a consistent independent predictor of mortality at all time points. Our results are supported by numerous studies, in which the NIHSS proved to be a strong predictor of mortality during hospitalization [17], at 30 days [18, 19], three months [19], one year [20], and even at five years post event [18]. This finding points to the key role of neurological status immediately after stroke, well reflecting the underlying ICH severity, and its continuing impact on survival throughout the post-stroke period.

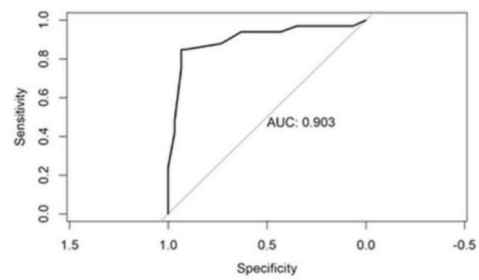
The MICH score (combining a subject's functional performance assessed by NIHSS score, age, hematoma volume, infratentorial origin and intraventricular extension of bleed) [16] proved to be an equally potent predictor of both short- and long-term mortality. Our study thus contributes to the scant data on the predictive value of ICH score in the longer follow-up [21].

A history of cardiac failure, myocardial infarction, and atrial fibrillation independently predicted post-ICH survival at various time points. These results demonstrate the impact of concurrent heart disease on survival. A recent study noted that atrial fibrillation is present in 21.9% of spontaneous ICH cases.<sup>21</sup> These patients, while receiving antithrombotic medication, had larger hematoma volume and higher three month mortality [22]. Others have noted that cardiac failure impacts post-ICH survival, increasing the risk of post-discharge mortality and hemorrhagic stroke recurrence within the first three years [23].

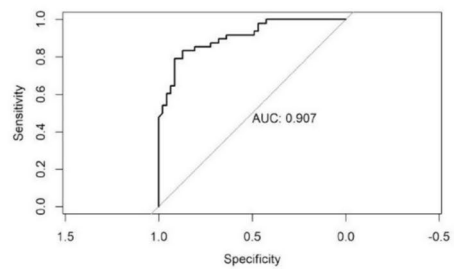
Model A predicting 30-day mortality



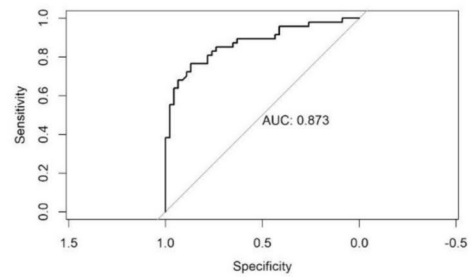
Model B predicting 30-day mortality



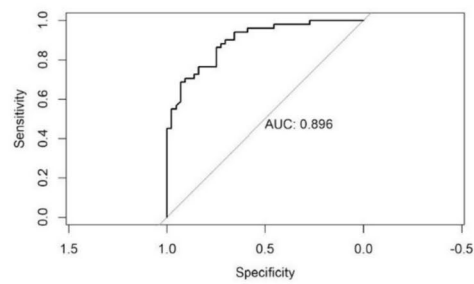
Model A predicting 6-month mortality



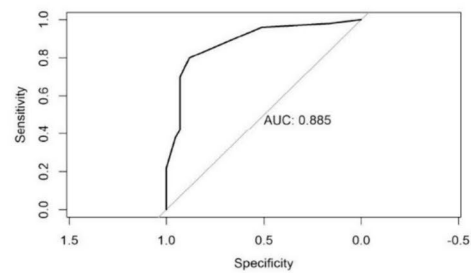
Model B predicting 6-month mortality



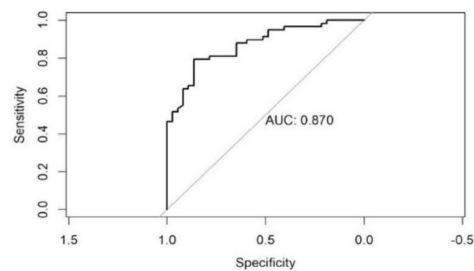
Model A predicting 1-year mortality



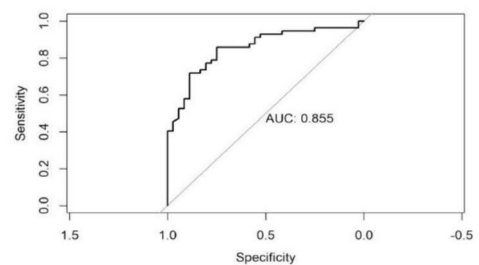
Model B predicting 1-year mortality



Model A predicting 3-year mortality



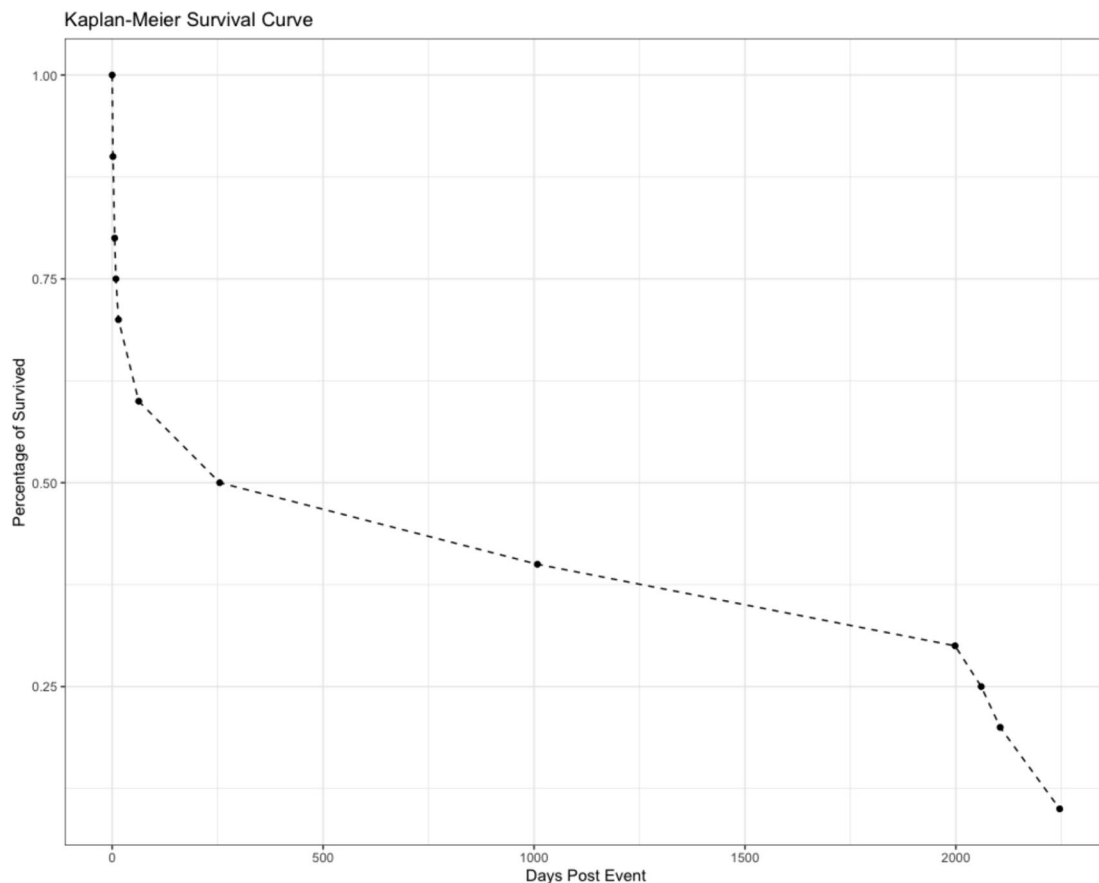
Model B predicting 3-year mortality



**Fig. 1** Sensitivity and specificity, as described by ROC curve and AUC, of both Models in respective follow-ups

Consistent with previous studies, measuring largest diameter of ICH proved to add value to the prediction model; and given its simplicity and close relation to hematoma volume [9], this parameter may be particularly useful in an emergency setting [24]. Also, sulcal or cisternal effacement may indicate an increased intracranial pressure, and thus signal a

developing hydrocephalus, which has previously been noted as an independent predictor of short-term mortality [14]. Further, hydrocephalus score serves as a good tool to assess and quantify hydrocephalus severity and thus better predict patient's outcome [14].



**Fig. 2** Kaplan–Meier survival curve, depicting the percentage of survivors in the days after the ICH event

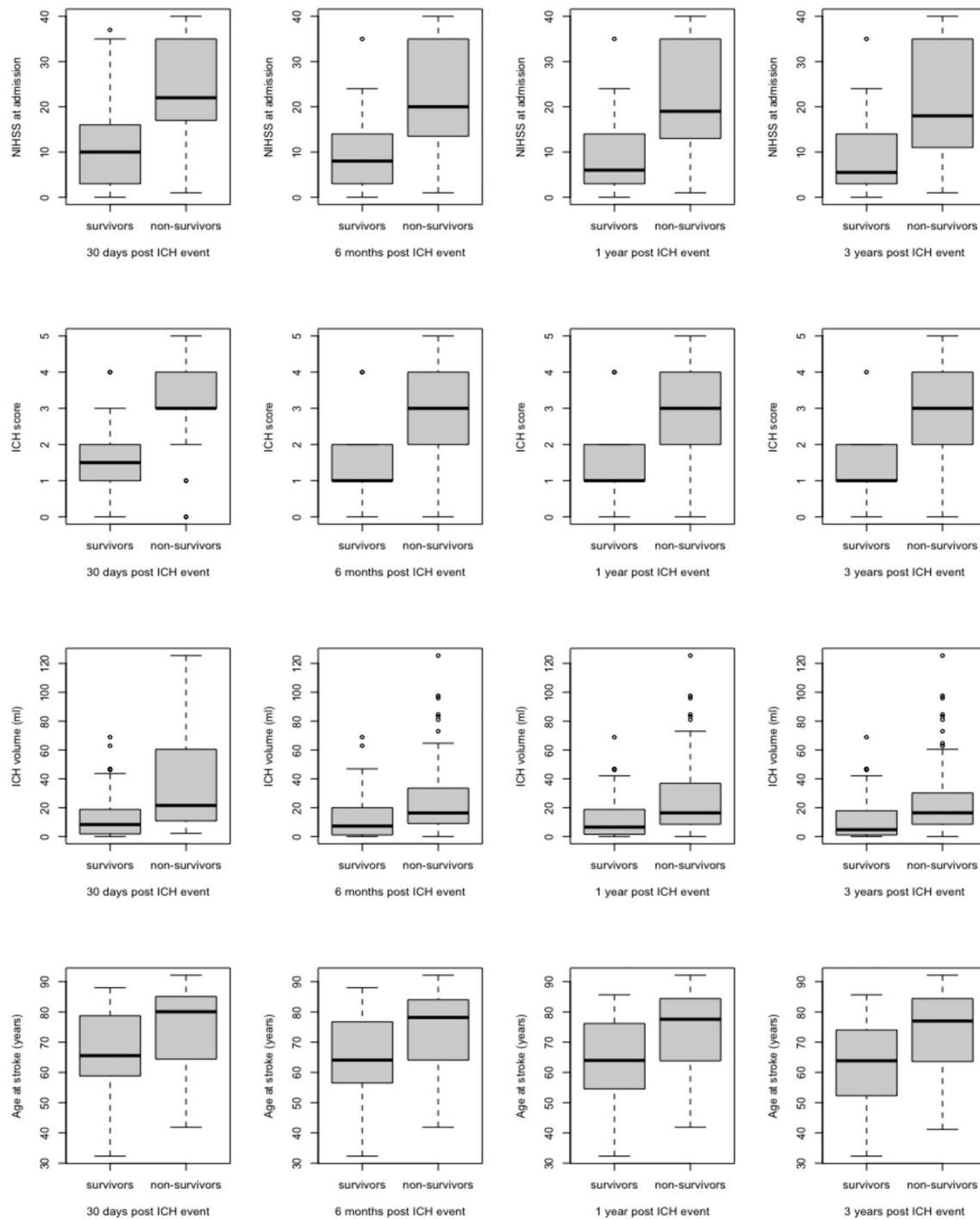
Similar to other studies [9, 20, 25], age, too, independently predicted mortality. Combining the effect of age and NIHSS, the Essen ICH score showed a high prognostic accuracy for complete recuperation and death 100 days post stroke [26]. One study on ICH in the oldest-old patients (over 85 years), however, questioned the criterion of age as an independent predictor of mortality, stating that in the oldest of patients, a higher hematoma volume on admission leads to the graver outcome rather than age-related comorbidities [27]. Consequently, age might be a better predictor in comparatively younger patients, losing its forecasting utility in the eldermost.

The clinical relevance of our findings is accompanied by the quick and easy measurement of the aforementioned variables, which helps to streamline the process of assessing clinical severity and prognosis immediately after hemorrhagic stroke. Overall, our results indicate that both the NIHSS and MICH scores are excellent predictors of mortality and well describe the underlying ICH severity.

Our study has several limitations. First, it is a retrospective study with the spontaneous source of clinical/radiologic data being CT scans and admission or discharge reports of variable quality. However, the quality of the CT scans and

discharge data was overall high, since all patients were treated in four large hospitals with stroke units (two of the four hospitals are university hospitals). Second, the cohort was relatively small and only patients with sufficiently detailed data were included [93 out of 134 patients (69%)], leading to a relatively lower power of our analysis due to reduced sample size and impacting on our ability to validly assess all potential predictors of mortality. However, there is generally a smaller sample size in ICH studies. Third, we could not include follow-up CT scans because these were missing for some patients, and therefore the effect of potential hematoma growth on outcome could not be explored [28]. Fourth, we did not collect data on eventual withdrawal or limitation of care; nonetheless, according to standard medical practice in the participating hospitals, the best possible intensive care is provided to patients with ICH.

Finally, in this study we analyzed only hospitalized cases of ICH. A previous study showed that over 7% of patients with ICH die prior to being admitted to hospital [29]. This most likely means that the mortality rates reported in this study are lower than the true rates. Also, the risk factor profile of patients surviving the hyperacute phase may be different from those who die before reaching hospital. Not



**Fig. 3** Box plots comparing individual parameters in survivors versus non-survivors after ICH in various time points

including the latter in our analysis might have confounded the predictors of mortality identified in this study and likely limits the generalizability of our results to hospitalized ICH patients only. Inclusion of autopsy data would have

mitigated this limitation, but these were not available to us. Nevertheless, we expect that all patients in the Brno area were presented to one of the cooperating hospitals, ie, no cases from the community were omitted other than due to

ultra-early mortality, because all patients with a suspected stroke are required to be transported to a hospital with a certified stroke unit as per the guidelines applicable in the whole Czech Republic (and all 4 hospitals with certified stroke unit were included) [6].

The uniqueness of our study lies in its community-based character, in the assessment of broad range of clinical (16) and radiological (15) variables, and the reporting on three-year mortality after ICH and its predictors, thus becoming, to the best of our knowledge, the first study assessing long-term mortality after ICH in Central Europe. As mentioned above, due to the inclusive and community-based nature of our study, these mortality data should be representative of an urban and suburban population in a post-communist Central European city.

## Conclusion

In this community-based study in Brno, CR, we found that severity of neurological deficit at admission, combined with age and size of ICH, well predicted short- and long-term mortality after spontaneous ICH. A history of cardiac failure, myocardial infarction, or atrial fibrillation at presentation were also predictors of mortality, underscoring the need for optimal cardiac management in patients with ICH.

**Supplementary Information** The online version contains supplementary material available at <https://doi.org/10.1007/s13760-024-02612-y>.

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**Author contributions** Albert Sterba collected data, helped design and interpreted the statistical analysis, wrote the manuscript; Petra Sedova collected data, helped design and supervised the study, revised the manuscript; Robert D. Brown Jr. supervised the study, helped with the study design, revised the manuscript; Albert Stehlik collected data; Tomas Bryndziar took part in establishing the study methodology, revised the manuscript; Petra Cimflova assisted in correct assessment of radiological variables; Silvie Belaskova and Ingrid Kovacova performer statistical analysis; Josef Bednarik helped with the collection of data; Robert Mikulik helped design and supervised the study, revised the manuscript. All coauthors critically revised the manuscript.

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## Declarations

**Conflict of interest** The authors have no conflict of interest to declare.

**Ethical approval** The present study conforms to the guidelines issued in the Declaration of Helsinki. This study was approved by the Institutional Ethics Committees (Ethics Committees of St Anne's University Hospital, University Hospital Brno, Hospital of Merciful Brothers, Military Hospital Brno, and Institute of Health Information and Statistics of the CR, RF. 36v/2014). Consent was waived by the IRB for this retrospective medical record review study, with no direct patient contact.

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