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Educational attainment, severity and short-term prognosis of intracerebral haemorrhage

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ABSTRACT

Background Educational attainment is a critical social determinant of health that impacts the risk and severity of incident ischaemic stroke, but less is known of its impact on intracerebral haemorrhage (ICH). The objective of this study is to determine whether educational attainment is associated with ICH severity and short-term prognosis.

Methods Subjects were enrolled in a prospectively ascertained cohort with primary ICH from 1994 to 2020 at Massachusetts General Hospital. Educational attainment, medical history of ICH risk factors, ICH volume and ICH score were obtained on admission. The primary outcomes were ICH volume and the ICH score.

Results Of 2539 eligible patients eligible, the median age of the sample was 74 (IQR 64–82) and 2159 (85%) had high school-only education. 1655 (65%) presented with an ICH volume less than or equal to 30 mL and 1744 (69%) presented with an ICH score less than 3. In multivariable logistic regression analyses controlling for age, income, employment history and prestroke diagnoses of hypertension and coronary artery disease, patients with high school-only education were more likely to have an ICH volume greater than 30 mL compared with college diplomates (OR 1.58, 95% CI 1.24 to 2.08) and more likely to have an ICH score of 3 or greater compared with college diplomates (OR 2.37, 95% CI 1.77 to 3.19).

Discussion Prestroke educational attainment is independently associated with ICH severity and short-term prognosis, with lower educational attainment associated with larger ICH volumes and higher ICH scores. Future studies should examine how educational attainment impacts exposure to traditional clinical risk factors.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ It is known that prestroke social determinants of health impact the risk for and outcomes after ischaemic stroke, but less is known about haemorrhagic stroke, specifically intracerebral haemorrhage (ICH).

WHAT THIS STUDY ADDS

⇒ In the largest study of an ICH cohort to date, we show that prestroke educational attainment is associated with the severity and short-term prognosis after ICH.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ This study suggests that further investigation is needed into the impact of social determinants, along with traditional clinical determinants, on haemorrhagic stroke.

INTRODUCTION

Healthy People 2030 highlights the important role of social determinants of health (SDOH) in impacting people's health and well-being, and the crucial contribution of SDOH to health inequities.[1 2] This framework specifically mentions education access and quality as an independent domain when considering the impact of SDOH on health and well-being. This classification is an essential distinction and has been highlighted in previous studies where educational attainment was identified as an independent risk factor for all-cause mortality and increased risk of cardiovascular and cerebrovascular disease.[3]

The importance of educational attainment has been studied primarily in ischaemic stroke models, showing that low educational attainment increases the risk for incident stroke, stroke severity and impact outcomes in stroke recovery.[3–9] Additionally, some studies have also found that higher levels of educational attainment act as a protective factor against stroke and are associated with improved cognitive recovery even after large ischaemic strokes.[6 7] However, much less is known about how educational attainment impacts haemorrhagic stroke, which is important given haemorrhagic stroke confers higher morbidity and mortality despite similar traditional clinical risk factors.[10]

Despite increasingly standardised and accessible care for acute clinical management of intracerebral haemorrhage (ICH), the prevalence and incidence of ICH have increased and inequitable outcomes after ICH have been described[11–18] suggesting factors apart

from traditional clinical determinants impact the risk and recovery from stroke. Given prior literature suggests a role for educational attainment in impacting risk and recovery for stroke, we hypothesise that in addition to traditional clinical risk factors, such as hypertension (HTN), educational attainment will be associated with ICH severity and prognosis. Further investigating this relationship could lead to novel insights on how social determinants impact exposure to known risk factors, and eventually influence interventions for primary and secondary prevention in those at highest risk for ICH. Therefore, this study aims to understand if educational attainment is associated with stroke severity and short-term prognosis on admission for ICH patients.

METHODS

Study design

We used data from the prospectively collected Massachusetts General Hospital (MGH) ICH cohort.[11] MGH is a tertiary care centre and triages ICH patients from regions all over New England, with most patients coming from the state of Massachusetts. Inclusion criteria are age over 18 and admission to the MGH Neuroscience Intensive Care Unit from January 1994 to January 2020 with a clinical and radiographically confirmed diagnosis of primary ICH. Exclusion criteria are those patients with missing clinical data of stroke severity that could not have an ICH score calculated, and those with ICH secondary to traumatic injury, brain tumour or a vascular malformation. Demographic data of age, sex and zip code information were collected. To evaluate the impact of traditional clinical risk factors on ICH severity, medical history collected included a diagnosis of HTN prior to admission, history of tobacco use, diabetes, coronary artery disease (CAD), atrial fibrillation, history of liver disease, diagnosis of dementia at the time of admission and history of prior haemorrhagic stroke. This study adhered to the Strengthening the Reporting of Observational Studies in Epidemiology observational cohort guidelines.[19] The deidentified data that support the findings of this study are available from the corresponding author, on reasonable request. Identifying data are not available given the participants of this study did not give written consent for their data to be shared publicly, so due to the sensitive nature of the research supporting data are not available.

Educational attainment and SDOH

The Healthy People 2020 framework guided the selection of SDOH to include these five domains: (1) economic stability, (2) education, (3) social/community context, (4) neighbourhood environment and (5) access to healthcare. The following SDOH were collected for all patients: median income, highest level of education, marital status, race and religion. All SDOH were included to understand the relationships and interactions between the variables.

Educational attainment was stratified as any high school education including some high school education and high school diplomate or college diplomate. This dichotomisation was chosen based on prior studies examining the relationship between education on mortality when comparing years of education versus the number of degrees completed; results showed that degrees completed are the dominant dimension even when controlling for total years of education.[20 21] Further, a true inflection point for decreased mortality occurs at 12 years of education, capturing the effect of a high school diploma.[20 22 23] 136 patients in our sample had some high school education but did not obtain diplomas; these patients collapsed into the category of any high school education given years of education were not available. In the American educational system, once individuals complete high school (usually 12 years of schooling), some pursue advanced education, termed college in America, otherwise referred to as university education globally.

Median annual income brackets were stratified into four groups: low-income representing <US$40 000 annually, middle-income representing US$40 000–US$75 000 annually, high-income representing US$75 000–US$100 000 annually, and a very high income representing >US$100 000 annually. Marital status was grouped by married, separated, single and widowed. Race was self-stated and grouped by white, black, Asian/Pacific Islander or multiple races and/or another race. Religions represented included Christian, non-Christian and non-affiliated. Preferred language was scored as yes for English, and no for any other language.

Stroke severity and short-term prognosis

Stroke severity served as the primary outcome and was measured using both ICH volume and the ICH score. ICH score is a previously published score, which also conveys some prognostic information, though it does have limitations.[24] To calculate the ICH score, the Glasgow Coma Scale, another previously published score, was used.[25] ICH volume was dichotomised by less than or equal to 30 mL or greater than 30 mL. ICH volume was chosen for severity given it does not require other variables for calculation, such as age, and has been considered the most significant clinical determinant of severity.[26] The ICH score was chosen as the measure of stroke severity and prognosis given it is widely used and captures the Glasgow Coma Scale on admission, age, location (supratentorial vs infratentorial) and volume of haemorrhage, and the presence of intraventricular haemorrhage. The ICH score is an ordinal categorical variable ranging from 0 to 6, which for this study was dichotomised into less than 3 and greater than or equal to 3.

Data analysis

Analyses were performed in R and R Studio (www.r-project.org). First, we compared baseline characteristics, medical history and SDOH among those with mild stroke versus severe stroke using the Wilcoxon rank sum test and χ^2 tests. Next, those factors which were significantly associated with stroke severity in

Table 1 Social determinants by ICH Volume

	ICH ≤30 mL (N=1655)	ICH >30 mL (N=884)	P value
Age	74 (63–82)	75 (66–82)	0.072
Income bracket			0.80
Low	79 (5%)	35 (4%)	
Mid	973 (59%)	526 (60%)	
High	394 (24%)	208 (24%)	
Very high	164 (10%)	83 (9%)	
Employment status			0.071
Disabled	50 (3%)	20 (2%)	
Employed	128 (8%)	48 (5%)	
Not employed	50 (3%)	22 (2%)	
Retired	1427 (86%)	794 (90%)	
Marital status			0.12
Married	908 (55%)	524 (59%)	
Separated	137 (8%)	60 (7%)	
Single	260 (16%)	138 (16%)	
Widowed	350 (21%)	162 (18%)	
Race			0.81
White	1400 (85%)	758 (86%)	
Black	97 (6%)	47 (5%)	
Asian/Pacific Islander	87 (5%)	47 (5%)	
Mixed or other	71 (4%)	32 (4%)	
Educational attainment			<0.0001
College diplomate	281 (17%)	98 (11%)	
Any high school	1374 (83%)	785 (89%)	
Religion			0.087
Christian	1308 (79%)	722 (82%)	
Non-Christian	127 (8%)	71 (8%)	
Unaffiliated	220 (13%)	91 (10%)	
English as preferred language			0.11
	1506 (91%)	821 (93%)	

Age was not normally distributed in the sample. Median values and interquartile range are reported, and the p-value is from a Wilcoxon Rank Sum test. Income brackets represent annual median salary with the following income brackets: low-income representing <$40,000 U.S dollars (USD), middle-income representing $40,000-$75,000 USD, high-income representing $75,000-$100,000, and very high income representing >$100,000 USD annually. Educational attainment was stratified as any high school education including high school diplomat, or college diplomat.
ICH, intracerebral haemorrhage.

Table 2 Social determinants of health and ICH score

	ICH score <3 (N=1744)	ICH Score ≥3 (N=795)	P value
Age	73 (64–81)	78 (66–84)	<0.0001
Income bracket			0.029
Low	87 (5%)	27 (3%)	
Mid	1001 (57%)	498 (63%)	
High	416 (24%)	186 (23%)	
Very high	183 (10%)	64 (8%)	
Employment status			0.0003
Disabled	56 (3%)	14 (2%)	
Employed	134 (8%)	42 (5%)	
Unemployed	60 (3%)	12 (2%)	
Retired	1494 (86%)	727 (91%)	
Marital status			0.22
Married	986 (57%)	446 (56%)	
Separated	147 (8%)	50 (6%)	
Single	265 (15%)	133 (17%)	
Widowed	346 (20%)	166 (21%)	
Race			0.68
White	1484 (85%)	674 (85%)	
Black	97 (6%)	47 (6%)	
Asian/Pacific Islander	88 (5%)	46 (6%)	
Mixed race or other	75 (4%)	28 (4%)	
Educational attainment			<0.0001
College diplomate	315 (18%)	64 (8%)	
Any high school	1429 (82%)	730 (92%)	
Religion			0.095
Christian	1381 (79%)	649 (82%)	
Non-Christian	133 (8%)	65 (8%)	
Not affiliated	230 (13%)	81 (10%)	
English as preferred language			0.88
	1597 (92%)	730 (92%)	

Age was not normally distributed in the sample. Median values and interquartile range are reported, and the p-value is from a Wilcoxon Rank Sum test. Income brackets represent annual median salary with the following income brackets: low-income representing <$40,000 U.S dollars (USD), middle-income representing $40,000-$75,000 USD, high-income representing $75,000-$100,000, and very high income representing >$100,000 USD annually. Educational attainment was stratified as any high school education including high school diplomat, or college diplomat.
ICH, intracerebral haemorrhage.

univariate analyses with a p<0.05 were then included in a logistic regression model; these factors included age, income bracket, employment status, educational attainment, history of HTN and history of CAD (tables 1–4).

Fewer than 100 participants were missing information on income bracket, education, history of HTN, history of diabetes, history of CAD, history of atrial fibrillation, history of dementia, history of prior haemorrhage and were excluded from analysis. More than 100 participants were missing for history of tobacco use and history of liver disease, respectively; these participants were assigned to a separate 'missing' category and included in the analysis. Participants with missing information on race were included in the 'other' category.

RESULTS

Study population

Of the 3186 patients in the MGH ICH cohort, 2539 patients had complete data for ICH score on admission. The median age in this sample was 74 (IQR 64–82) and 2159 (85%) had high school-only education, including diplomates and those with some high school education.

Table 3 Pre-ICH medical history stratified by ICH volume

	ICH ≤30 mL (N=1655)	ICH >30 mL (N=884)	P value
Hypertension			0.0009
	1341 (81%)	668 (76%)	
Sex			0.62
Female	763 (46%)	417 (47%)	
Smoking			0.70
Current	194 (12%)	96 (11%)	
History	568 (34%)	260 (29%)	
Never	622 (38%)	309 (35%)	
Missing	271 (16%)	219 (25%)	
Diabetes			0.39
	368 (22%)	183 (21%)	
Coronary artery disease			0.72
	362 (22%)	188 (21%)	
Atrial fibrillation			0.61
	367 (22%)	188 (21%)	
Liver disease			0.64
	58 (4%)	27 (3%)	
Missing	191 (12%)	120 (14%)	
Dementia			0.58
	225 (14%)	112 (13%)	
Prior haemorrhage			0.52
	147 (9%)	85 (10%)	

Most diagnoses were recorded as yes/no responses, unless otherwise indicated. Pre-stroke medical history of smoking and liver disease had missing responses for over 100 participants.
ICH, intracerebral haemorrhage.

Table 4 Pre-ICH medical history stratified by ICH score

	ICH score <3 (N=1744)	ICH score ≥3 (N=795)	P value
Hypertension			0.63
	1377 (79%)	632 (79%)	
Sex			0.37
Female	800 (46%)	380 (48%)	
Smoking			0.36
Current	216 (12%)	74 (9%)	
History	606 (35%)	222 (28%)	
Never	659 (38%)	272 (34%)	
Missing	263 (15%)	227 (29%)	
Diabetes			0.41
	371 (21%)	180 (23%)	
Coronary artery disease			0.003
	349 (20%)	201 (25%)	
Atrial fibrillation			0.15
	367 (21%)	188 (24%)	
Liver disease			1.0
	59 (3%)	26 (3%)	
Missing	202 (12%)	109 (14%)	
Dementia			0.49
	238 (14%)	99 (12%)	
Missing	28 (2%)	21 (3%)	
Prior haemorrhage			0.50
	165 (9%)	67 (8%)	

Most diagnoses were recorded as yes/no responses, unless otherwise indicated. Pre-stroke medical history of smoking and liver disease had missing responses for over 100 participants.
ICH, intracerebral haemorrhage.

In contrast, 379 (15%) patients were college diplomates. Most patients, 1499 (59%) were identified in the middle-income bracket, and most patients, 2158 (85%), in this sample were white. Additionally, most patients were married (1432 or 56%), retired (2221 or 87%) and most reported English as their preferred language (2327 or 98%). Notably, 2009 (79%) of patients had a prestroke diagnosis of HTN and 232 (9%) had a prior ICH recorded. Additionally, 80.2% of those with high school-only education had a chart-history of HTN and 77.4% of college diplomates had a chart history of HTN. The odds of having a history of HTN were not significantly different between the groups (OR 1.18, 95% CI 0.94 to 1.49).

Primary outcome analysis

In our cohort of 2359 patients, 1655 (65%) presented with an ICH volume of less than or equal to 30 mL and 884 (35%) presented with an ICH greater than 30 mL (table 1). In a univariate analysis examining social determinants by ICH volume, age, income bracket, employment status, marital status, race, religion and preferred language were not significantly different between those with a small volume ICH and those with large-volume ICH (table 1). However, college graduates comprised only 11% of large-volume ICH compared with those with any high school education who comprised 89% of large-volume ICH, with a p<0.0001 for educational attainment (table 1).

Similarly, of 2359 patients 1744 (69%) presented with ICH score less than 3 and 795 (31%) presented with ICH score 3 or greater (table 2). The median age of those with mild strokes was 73, compared with 78 for those with severe strokes (table 2). In a univariate analysis examining social determinants by ICH score, marital status, race, religion and preferred language were not significantly different between those with lower or higher ICH scores (table 2). However, those with lower ICH scores were younger, and college graduates comprised only 8% of high ICH scores compared with those with any high school education who comprised 92% of high ICH scores, with p<0.0001 for both age and educational attainment (table 2). Of note, age and employment status were significantly associated with ICH score but not ICH volume, likely because the ICH score accounts for age in its calculation.

Age was not normally distributed in the sample. Median values and IQR are reported, and the p value is from a Wilcoxon rank sum test. Income brackets represent annual median salary with the following income brackets: low-income representing <US$40 000, middle-income representing US$40 000–US$75 000=, high-income representing US$75 000–US$100 000, and very high income

representing >US$100 000 annually. Educational attainment was stratified as any high school education including high school diplomat or college diplomat.

Tables 3 and 4 summarise the association of medical history prior to ICH by the two selected measures of stroke severity. In the univariate analysis by ICH volume, only HTN was significantly associated with lower volume ICH with p<0.001 (table 3). Similarly, in a univariate analysis by ICH score, only CAD was associated with higher ICH score with a p value of 0.003 (table 4). Otherwise, sex, smoking, diabetes, history of atrial fibrillation, liver disease, dementia, nor prior haemorrhage were significantly different between those with higher or lower ICH volumes or ICH scores (tables 3 and 4).

Based on the univariate analyses of SDOH and medical history, multivariable logistic regression models adjusted for age, educational attainment, income level, employment status and prestroke diagnosis of HTN and CAD revealed a significant adjusted association for education level for both ICH volume and ICH score. When severity was assessed by ICH volume, those with high school-only education were 1.58 times more likely to present with a larger ICH volume when compared with college diplomates (OR 1.58, 95% CI 1.24, 2.08). When severity and short-term prognosis were assessed by ICH score, those with high school-only education were 2.37 times more likely to present with a higher ICH score when compared with college diplomates (OR 2.37, 95% CI 1.77 to 3.19). The long-term prognosis was examined by using modified Rankin Scores at 12 months and is presented in online supplemental analysis.

DISCUSSION

Our results indicate that prestroke educational attainment is an independent predictor of ICH severity and short-term prognosis; those patients with high school-only education were 1.61 times more likely to have an ICH volume of greater than 30 mL and 2.37 times more likely to have a high ICH score when compared with college diplomates. In our sample, 85.0% of patients had some high school education, with most being high school diplomates (78.3%), and 14.9% of patients were college diplomates. US Census data for educational attainment from 1940 to 2000 was published in 2006 by deciles of age; for adults over the age of 50, the average percentage of high school diplomates was 73.8%.[27] While more current census data by age decile are not yet available, the percentage of the population with high school diplomas continues to increase; in 2011, 87.6% of people over the age of 25 had high school diplomas which increased to 91.1% in 2021.[28] Our cohort was recruited from 1994 to 2020 and likely represents a slightly more educated population than the national average. However, even in a slightly more educated cohort, the effect of educational attainment impacted stroke severity and prognosis, highlighting the role of social determinants in haemorrhagic stroke.

Despite decades of investigative trials and research in haemorrhagic stroke, few studies have explored the role of educational attainment in a stroke population. One study showed that while higher educational attainment was protective for incident ischaemic strokes, the same relationship was not true for haemorrhagic stroke patients.[29] However, this study examined only 97 total cases of haemorrhagic stroke. Our findings represent a much larger sample and align with previous studies examining the effect of education on all-cause mortality, cardiovascular events and ischaemic stroke.[9 30] The novel findings that educational attainment impacts ICH severity and short-term prognosis implies two potential mechanisms. First, educational attainment could be a surrogate marker for other social determinants that impact overall health; for example, those with lower education likely had less exposure or access to preventative health services or had more exposures to environments that worsened traditional clinical risk factors.[4 7 20 22 23 30 31] Similarly, those with higher education may have had more exposure to health services through their life course or had more exposures to environments that decreased traditional clinical risk factors. A recent large, international prospective cohort study across 21 diverse countries also found that in 155 722 patients, low education was more predictive of all-cause mortality than HTN, and contributed just as much, if not more, attributable risk for both cardiovascular and stroke events than tobacco use.[3]

A second potential mechanism is that educational attainment impacts health literacy and the ability to access, understand and navigate a complex health system and eventually leads to increased exposure to traditional clinical risk factors or less access to healthcare. For several years, there have been dedicated efforts to implement universal precautions to use plain language in primary care settings to make information more accessible, understandable and actionable for patients.[32 33] However, these principles have not yet influenced primary or secondary prevention strategies for stroke. Our finding that educational attainment is associated with stroke severity has important clinical implications for stroke care, health literacy, and health equity and healthcare access for all patients.

Limitations of this study include the relatively homogeneous population of patients admitted to MGH; most of our patients are racially white and are classified as middle income. Our cohort also represents an older population than in previously studied stroke cohorts.[9 12 13 31 34] Both limitations restrict the generalisability of our findings, and future studies should replicate our results with more diverse cohorts of ICH patients. However, despite the relative racial homogeneity of this population, educational attainment was similar to national levels from 1994 to 2020. Next, we did not record a number of years of education for those 170 patients in our sample without high school diplomas. We also did not have this information for the rest of our cohort. We instead chose a dichotomisation of educational attainment based on extensive

prior research suggesting the dominant dimension of degrees, not years of education, in mortality or disease-specific outcomes. Lastly, a notable finding in our results was that a prestroke diagnosis of HTN was an independent predictor of the ICH volume but not ICH score. The limitation of our measure of HTN is a dichotomous yes/no measure and does not capture the severity or duration of a patient's HTN leading to decreased specificity of the value measured. Additionally, this measurement may reflect some misclassification bias; patients without a documented medical history of HTN could have still been hypertensive in the ambulatory settings. Therefore, a more accurate ambulatory blood pressure history could have further helped understand the relationship between educational attainment and ICH severity.

Future studies should investigate the impact of educational attainment on stroke recovery in more diverse populations, as other social determinants not captured in our cohort could play an impactful role besides educational attainment alone. Next, given that the link between education and stroke risk is now established, future studies should focus on identifying the impact of educational attainment on exposures to traditional clinical risk factors, healthcare access and health-related behaviours prior to incident stroke. Our findings demonstrate the need for further research to elucidate the relationship between the social determinants of health in ICH.

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Contributors Study concept and design: NY, PR, CDA and JR. Acquisition, analysis and interpretation of data: NY, PR and JR. Drafting of the manuscript and critical revisions for important intellectual content: NY, PR, AG, CK, SM, EM, LP, LR, CDA and JR. Statistical analysis: NY, PR and SM. NY serves as the guarantor of this study.

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Competing interests None declared.

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Data availability statement Data are available on reasonable request. The deidentified data that support the findings of this study are available from the corresponding author, on reasonable request.

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