# Supplementary Methods

## Study inclusion and exclusion criteria

We performed a retrospective analysis of prospectively collected data drawn from the ongoing longitudinal intracerebral hemorrhage (ICH) study conducted at Massachusetts General Hospital (Boston, MA, USA).[1] Study subjects were consecutive patients admitted to Massachusetts General Hospital between January 1st 2006 and December 31st 2017 with a diagnosis of spontaneous ICH. All participants were aged 18 years or older at time of acute primary (i.e., spontaneous) ICH. The initial ICH diagnosis was formulated by the attending stroke neurologist and confirmed via computed tomography (CT) scan obtained within 24 hours of symptoms' onset. Patients with intracranial hemorrhage due to trauma, conversion of an ischemic infarct, rupture of a vascular malformation or aneurysm, or brain tumor were not considered eligible. Because we sought to study the association between hearing loss and neurological recovery during the first year after ICH, we excluded patients who died before 12 months from the acute hemorrhage.

## Enrollment, baseline data collection, and longitudinal follow-up

Following screening and enrollment, participants or reliable informants were interviewed in-person by dedicated study staff.[2] Demographic, social, and medical history information were collected, including self-reported race and ethnicity. Study staff conducted follow-up phone interviews blinded to baseline and neuroimaging information at 3, 6, and 12 months after ICH. The Enterprise Data Warehouse (EDW), a secure data storage and retrieval platform for institutions in our healthcare delivery network, was used to augment patient-provided information with Electronic Health Records (EHR). The EDW was used to obtain additional information on medical visits and social determinants of health. Manual review of EHR was used to attempt to fill in missing data. Data remaining missing after manual review were imputed using random sampling of existing values. Median incomes were captured at the zip code level using a publicly available database (https://www.psc.isr.umich.edu/dis/census, accessed on March 1st, 2021).

## CT and magnetic resonance imaging data capture and analyses

Admission CT scans were analyzed to determine ICH location, hematoma volume, and volume of intraventricular blood according to a previously validated methodology.[3] Magnetic resonance imaging (MRI) Images were obtained using a 1.5 or 3.0 Tesla magnetic resonance scanner, according to a previously validated protocol.[4] Neuroimaging markers of cerebral small vessel disease (CSVD) severity (white matter hyperintensities, cerebral microbleeds, expanded perivascular spaces, lacunes, and cortical superficial siderosis) were rated according to STandards for ReportIng Vascular changes on nEuroimaging (STRIVE) consensus criteria, as previously described.[5] Based on a recently described and validated total CSVD score, we rated microvascular disease burden on an ordinal scale from 0 to 6.[4,6] We also evaluated total cerebral amyloid angiopathy burden on MRI using a validated ordinal score that ranges from 0 to 6,[7] and total hypertensive arteriopathy burden on MRI using a validated ordinal scale ranging from 0 to 4.[8]

## Hearing loss diagnosis

We initially screened for diagnosis of hearing loss utilizing encounter information available for each inpatient and outpatient visit. We then utilized a two-stage process (natural language processing analysis followed by manual review) to extract from EHR (within 6 months before or after MRI) confirmation of diagnosis of hearing loss in the form of: (1) active medical problem; (2) physical exam findings; (3) mention by healthcare provide in review of systems (within 6 months before or after MRI); and (4) audiogram with consistent findings. The initial natural language processing analysis utilized for positive hearing loss identification instances of the following terms: "hearing loss," "hearing impair," or "hard of hearing." Occurrences where the terms "denies," "negative," "mother," "father," or "no " appeared within the same sentence were excluded from receiving a hearing loss diagnosis. Participants with a first mention of hearing loss prior to or within 6 months of MRI were considered to have screened positive for diagnosis of hearing loss. All hearing loss diagnoses were then confirmed by manual review of EHR from a board-certified physician, who proceeded to review medical records to confirm: (1) that hearing loss was present on the screening encounter information and (2) that corroborating evidence could be extracted from EHR in the form of an active medical problem (in past medical history and review of system), or exam finding of hearing impairment (as part of physical exam), or diagnosis based on audiogram (tracings and report were individually reviewed for confirmation). Individuals whose hearing impairment was documented to be unilateral (based on either physical exam or audiogram findings) were included among participants who received a diagnosis of hearing loss. In order to test the performance of our hearing loss diagnosis approach, we extracted from our medical records detailed hearing performance information for all study participants who underwent a formal audiogram (n=37). Our EHR-based approach (natural language

processing analysis followed by manual review by physician) had sensitivity of 95% and specificity of 93% for hearing loss diagnosis (after removing audiogram data extraction from the EHR approach).

## Outcomes' capture

We captured information on functional performance status by computing the modified Rankin Scale (mRS) via the simplified mRS questionnaire.[9] We administered the questionnaire and computed mRS at discharge, 3 months, and 12 months after ICH. We then subdivided participants based on changes in mRS between 3 and 12 months after ICH in the following groups: (1) functional decline (i.e., higher mRS at 12 months vs. 3 months); (2) functional stability (i.e., same mRS at 12 months vs. 3 months); (3) functional recovery (i.e., lower mRS at 12 months vs. 3 months).[10] We defined cognitive recovery by combining two sources of information. First, a board-certified neurologist conducted a manual review of all EHR to quantify cognitive performance at 3 and 12 months after ICH. Specifically, we extracted information on functional status (i.e., ability to perform activities of daily living and instrumental activities of daily living) and cognitive performance (derived from standardized testing as reported in physician, nursing and rehabilitation/therapy notes) to categorize patients as either: (1) normal cognitive performance; (2) minor neurocognitive disorder (according to DSM-5 criteria); or (3) major neurocognitive disorder (also per DSM-5 criteria).[11] Participants also underwent cognitive testing evaluation during phone-based research interviews at 3 and 12 months after ICH using the modified telephone interview for cognitive status (TICS-m), as previously described.[3] Of note, as in prior studies we included a validated phone-based hearing screen to ensure validity of results. We then utilized previously identified cut-offs to classify participants as normal cognitive performance, minor neurocognitive disorder, or major neurocognitive disorder.[12] Discrepancies in cognitive performance status adjudication between EHR and TICSm (n=16/737 participants, 2.2%) were referred to a panel of three board-certified neurologists for resolution. Among individuals with cognitive impairment at 3 months (major or minor neurocognitive disorder), we identified those who experienced cognitive recovery at 12 months based on either: (1) resolution of cognitive deficits (i.e., return to normal cognition); or (2) improvement from major to minor neurocognitive impairment). Study staff administering study questionnaires and performing EHR review were blinded to all clinical and neuroimaging information (including hearing loss status).

## Statistical analyses

T-tests, chi-squared tests, and fisher exact tests were performed to identify univariable relationships with hearing loss diagnosis. Variables with univariable association with diagnosis of hearing loss at $P<0.20$ were included in multivariable logistic regression, with Akaike information criterion (AIC) used to determine the final model. We then performed univariable and multivariable analyses of likelihood to experience functional or cognitive recovery among study participants. Univariable analyses utilized identical methodology as described above for univariable analyses of hearing loss. For functional recovery, we created an ordinal logistic regression model quantifying likelihood of experiencing decline, stability, or improvement in functional performance, as defined by changes in mRS score between 3 and 12 months after ICH. For cognitive recovery, we created a logistic regression model quantifying likelihood of experiencing improvement in cognitive performance among participants diagnosed with minor or major neurocognitive disorder at 3 months after ICH. Specifically, cognitive recovery at 12 months was defined as: (1) return to normal cognition for participants diagnosed with minor neurocognitive disorder at 3 months or (2) return to normal cognition or improvement to minor neurocognitive disorder for participants diagnosed with major neurocognitive disorder at 3 months. We included in multivariable modeling all variables with univariable association with either functional or cognitive recovery status at $P<0.20$. We pre-specified adjustment (regardless of univariable association results) for age, sex, and self-reported race/ethnicity. Owing to the limited number of non-white participants in our study, we opted to adjust for white versus non-white race/ethnicity. We also pre-specified adjustment for discharge mRS for functional recovery multivariable modeling.[10] We then used AIC, followed by pruning of variables with association above the pre-specified threshold (i.e., $P>0.05$) to arrive at two separate final models. Variance inflation factors (VIF) were calculated with pre-defined threshold of VIF >5 for variables with univariate associations with each outcome. No variables exceeded this threshold in either model, so none were excluded. Analyses were performed using R version 4.0.2 (R Foundation for Statistical Computing, Vienna, Austria).

## Ethical statement

This study was approved by the Institutional Review Board of Massachusetts General Hospital (approval number: 2021P001340). Written informed consent was obtained from all patients or their representatives.


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## Supplementary References

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