Radiological Investigation of Spontaneous Intracerebral Hemorrhage
Systematic Review and Trinational Survey

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Background and Purpose—It is not always clear whether, how, and when to undertake further radiological investigation of spontaneous (nontraumatic) intracerebral hemorrhage (ICH).

Methods—We systematically reviewed Ovid MEDLINE and EMBASE databases for studies of the diagnostic utility of radiological investigations of the cause(s) of ICH. We sent a structured survey to neurologists, stroke specialists, neurosurgeons, and neuroradiologists in the United Kingdom, the Netherlands, and France to assess whether, how, and when they would investigate supratentorial ICH.

Results—This systematic review detected 20 relevant studies (including 1933 patients), which either quantified the yield of a radiological investigation/imaging strategy (n=15) or compared 2 imaging techniques (n=5). Six hundred ninety-two (49%) physicians responded to the survey. Further investigation would have been undertaken by the following: 99% of respondents, for younger (38 to 43 years), normotensive adults with lobar or deep ICH; 76%, for older (age 72 to 83 years), normotensive adults with deep ICH; and 31%, for older adults with deep ICH and prestroke hypertension. Younger patient age was the strongest influence on the decision to further investigate ICH (odds ratio=16; 95% confidence interval, 13 to 20), followed by the absence of prestroke hypertension (odds ratio=5; 95% confidence interval, 4 to 6) and lobar ICH location (odds ratio=2; 95% confidence interval, 1 to 2).

Conclusions—The paucity of studies on the diagnostic utility of imaging investigations of the cause(s) of ICH may contribute to the variation observed in when and how and which patients are investigated in current clinical practice. Studies comparing different types of diagnostic strategies are required. (Stroke. 2010;31:00-00.)

Key Words: intracerebral hemorrhage imaging etiology systematic review survey

Swift diagnosis of the underlying cause of intracerebral hemorrhage (ICH) directs treatment to improve outcome or prevent recurrent ICH.1 In current clinical practice, physicians seem to attribute the cause of ICH on the basis of a history suggestive of particular causes, the presence of associated risk factors, or the detection of underlying structural abnormalities.2 Decisions about whether and how to use radiological investigations other than computed tomography (CT) to determine ICH cause seem to be based on 3 principal factors: patient age, ICH location, and the existence of prestroke systemic arterial hypertension.3,4

Some studies have suggested that patients with putaminal hemorrhages should not routinely undergo cerebral angiography5 or that diagnostic cerebral angiography should not be considered in patients with spontaneous ICH who are older than 45 years and have preexisting hypertension and thalamic, putaminal, or posterior fossa ICH.4 Others have argued that the decision to investigate a patient with ICH should be primarily based on the patient’s clinical condition rather than on the site of the hemorrhage.3 This strategy is supported by the observation that the association between high blood pressure and deep (as opposed to lobar) ICH is only modest.6

Because the recommendations of the American Heart Association and European Stroke Organization on the investigation of ICH are based on low levels of evidence,7,8 we systematically reviewed the literature to investigate the diagnostic utility of radiological techniques performed after initial axial, unenhanced CT to identify structural abnormalities underlying ICH. In addition, we assessed everyday clinical practice by a survey of members of professional organizations involved in the investigation of patients with ICH in 3 European countries.
Methods

Systematic Literature Review

Literature Search Strategy
One reviewer (C.C.) searched Ovid MEDLINE from 1966 and EMBASE from 1980 to April 25, 2007, by using an 8-line electronic search strategy (supplemental Figure I, available online at http://stroke.ahajournals.org), supplemented by the authors’ personal files, manually searching the bibliographies of articles retrieved by the electronic search, and surveillance of relevant journals’ electronic tables of contents. We restricted this review to published data but not to language of publication. Titles and abstracts of retrieved citations were screened by C.C., and potentially suitable studies were read in full by C.C. and R.A.-S.S., who extracted relevant data and resolved disagreements by discussion.

Critical Appraisal
Guided by a checklist of ideal characteristics for a study of radiological investigation based on the principles of the QUality Assessment of Diagnostic Accuracy Studies9 and Standards for the Reporting of Diagnostic accuracy studies,10 we sought generalizable investigations on the basis of the techniques used: CT (CT angiography [IADSA]), magnetic resonance (magnetic resonance imaging [MRI], magnetic resonance angiography [MRA], and MR venography), and intra-arterial digital subtraction angiography (IADSA). We calculated proportions, $\chi^2$ values, and univariable odds ratios with SPSS version 14.0 and calculated 95% confidence intervals (CIs) with Confidence Interval Analysis software.11 We did not perform multivariable analyses because each respondent rated the 8 scenarios (some of which possessed similar characteristics of interest), and therefore, the statistical assumption of independence was not met.

Data Extraction and Statistical Analysis
We extracted the numbers of underlying structural abnormalities in total and in subgroups (by age, prestroke hypertension, and ICH location) in categories (1) and (2) in the previous paragraph and the sensitivity, specificity, and predictive values of radiological investigations in category (3). We calculated proportions and 95% confidence intervals (CIs).11

Trinational Survey of Professional Organizations

Survey Design
We sent by post a structured questionnaire (supplemental Figure II, available online at http://stroke.ahajournals.org) with 8 case vignettes that differed in terms of the following characteristics: ICH location (lobar or deep); prestroke hypertension (present or absent); and age (4 cases were <45 years [38, 39, 41, and 43 years of age] and 4 cases were >45 years [72, 75, 80, and 83 years of age]). We identified the survey target group from the professional organizations for stroke specialists, neurologists, neurosurgeons, and neuroradiologists in France, the United Kingdom, and the Netherlands (supplemental Figure III, available online at http://stroke.ahajournals.org). We determined the number of questionnaire recipients in each country (France=570, United Kingdom=568, and Netherlands=272) by identifying the smallest of its professional societies and taking an equal random sample of the membership of each of the country’s other societies. We sent nonresponders a reminder 3 months later.

Statistical Analyses
We restricted analyses to responders who confirmed that they were involved in the investigation of adults with ICH. We grouped respondents into their primary professional affiliation. Stroke specialists were neurologists in the Netherlands and France but tended to be general physicians in the United Kingdom. We grouped investigations on the basis of the techniques used: CT (CT angiography and CT venography), magnetic resonance (magnetic resonance imaging [MRI], magnetic resonance angiography [MRA], and MR venography), and intra-arterial digital subtraction angiography (IADSA). We calculated proportions, $\chi^2$ values, and univariable odds ratios with SPSS version 14.0 and calculated 95% confidence intervals (CIs) with Confidence Interval Analysis software.11 We did not perform multivariable analyses because each respondent rated the 8 scenarios (some of which possessed similar characteristics of interest), and therefore, the statistical assumption of independence was not met.

Results

Systematic Literature Review
The electronic searches of MEDLINE and EMBASE detected 5269 articles, of which 20 studies involving 1933 patients were suitable for inclusion. Twelve studies described the yield of a single investigation.5,12–21 Investigation yield was mostly concerned with IADSA,4,5,12–14,17,18,21 but 1 study concentrated on CT angiography20 and 3, on MRI.15,16,19 Three nonrandomized studies described the yield of strategies of delaying IADSA3,22 or of IADSA or CT/MRA for putaminal hemorrhage.23 The 5 remaining studies compared 1 investigation for the identification of ICH cause against another, without blinding the readers.24–28

Critical Appraisal
Generalizability of some studies was limited by their inclusion of a few patients with pure subdural,4,21 pure subarachnoid,16,20,21 or pure intraventricular4,5,15,17,18,21 hemorrhage. Most studies were affected by selection bias because they were retrospective assessments of how hospitalized patients with ICH had been investigated in everyday clinical practice (usually at tertiary referral centers, in neurosurgical units) with 1 exception.7 Few studies enrolled consecutive patients,2,28 because either they were undergoing an investigation (and were well enough to do so) or the ICH location was a determinant of the patient’s inclusion. The proportions of cohorts investigated ranged from 23% undergoing MRI after hospital admission16 to 65% undergoing immediate or delayed IADSA after hospital admission.3 Participants were often further selected for investigation by age,18 the location of their ICH,3,22,23,25 or whether the ICH extended into intraventricular, subdural, or subarachnoid compartments.12 Only 4 studies standardized timing of the investigation.14,17,22,26 Most of the studies were performed in the 1980s and 1990s; since then, IADSA and MRI technology and availability have improved. Furthermore, IADSA did not always include selective injections of all vascular territories. In the studies involving MRI, magnet strength was 0.5 T15 or 1.5 T.16,19,28 One study mentioned that T2* gradient-recalled echo sequences were used when appropriate,16 and the other 4 did not use T2* gradient-recalled echo sequences.15,19,22,28 One study did not mention the type of MRI used for follow-up.22

Yield of 1 Investigation
Twelve studies described the yield of 1 investigation.4,5,12–21 Some of these studies contributed to the total of 726 patients with ICH in whom it was possible to calculate the yield of
Yield of a Strategy
Three studies described the yield of a strategy for investigating ICH. Three studies identified consecutive admissions with ICH and compared 2 prespecified approaches to IADSA timing: the prevalence of underlying AVMs was 20% (95% CI, 17 to 23) and of aneurysms, 13% (95% CI, 11 to 16; Table 1). Sex of the patients did not appear to influence yield in the individual studies, but the pooled results showed that the yield was relatively low in patients with pre-stroke hypertension and in those with a deep ICH location (Table 1).

Yield of a Strategy

Diagnostic Utility of Radiological Techniques
Five studies compared a radiological technique against a reference standard (either another radiological technique, or operative or pathological findings) for identifying any structural abnormality underlying the ICH. In 1 study, individual data could not be extracted. The 4 remaining studies compared DSA-MRA against IADSA (11 patients with ICH; no false-positives or false-negatives), 3-dimensional CT angiography against IADSA (31 patients with hyper acute ICH; no false-positives or false-negatives). CT angiography against surgical findings (61 patients with massive, acute ICH requiring surgical decompression; sensitivity=55%, 95% CI, 38 to 71; specificity=97%, 95% CI, 83 to 99; positive predictive value=94%, 95% CI, 74 to 99; and negative predictive value=67%, 95% CI, 53 to 80). The preferred option was a “dynamic” CT angiography against IADSA (44 patients with spontaneous lobar ICH; sensitivity=88%, 95% CI, 69 to 96; specificity=95%, 95% CI, 76 to 99; positive predictive value=95%, 95% CI, 78 to 99; and negative predictive value=86%, 95% CI, 66 to 95).

Trinational Survey of Professional Organizations
Survey Response
We sent 1410 questionnaires. There were 692 (49%) respondents, of whom 617 (44%) were involved in the investigation of patients with ICH (supplemental Figure IV, available online at http://stroke.ahajournals.org). The proportion of physicians who responded was higher for France than for the Netherlands or the United Kingdom (P<0.001). The proportion of responders differed among professional groups (P<0.001): 51% of stroke specialists (n=180), 46% of neurosurgeons (n=161), 44% of neuroradiologists (n=155), and 34% of neurologists (n=121). The completeness of the responses received was excellent (median completeness=99%; range, 89% to 100%).

Survey Results
Extent of Investigation
The proportion of respondents who decided to perform 1, 2, or 3 investigations varied considerably among the 8 cases (the Figure). For example, the case of the patient age 41 years with a lobar ICH and no pre-stroke hypertension attracted the greatest proportion of respondents who would investigate once, twice, or 3 times (99%, 87%, and 56%, respectively), whereas these proportions were lowest (31%, 6%, and 1%, respectively) for the case of the patient age 83 years with a deep ICH and pre-stroke hypertension. The strongest influence on the decision to investigate at all was younger patient age, followed by the absence of pre-stroke hypertension, and these influences remained but were weaker as the decision to further investigate was made (Table 2). There was no significant difference among countries in the proportion of physicians investigating once. The proportions of physicians investigating twice (P<0.001) or 3 times (P=0.03) differed among countries, with French physicians tending to investigate more (supplemental Figure V, available online at http://stroke.ahajournals.org). Differences were also observed among specialties (P<0.001): neurosurgeons less frequently requested investigations (supplemental Figure VI, available online at http://stroke.ahajournals.org). Despite the consistency in respondents’ decisions to investigate non-hypertensive, younger patients with lobar or deep ICH (97% to 99%), they were less consistent about a hypertensive younger patient with a deep ICH, whom 89% of respondents would investigate once and 57%, twice.

Table 1. Prevalence and 95% CIs of AVMs and Aneurysms Based on 9 Studies in Which 726 Patients With ICH Were Investigated With Catheter Angiography

<table>
<thead>
<tr>
<th>Location</th>
<th>AVMs</th>
<th>Aneurysms</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Percent</td>
<td>95% CI</td>
</tr>
<tr>
<td>Overall</td>
<td>20</td>
<td>17 to 23</td>
</tr>
<tr>
<td>Age*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Young (&lt;50 y)</td>
<td>27</td>
<td>19 to 37</td>
</tr>
<tr>
<td>Old (≥50 y)</td>
<td>18</td>
<td>13 to 24</td>
</tr>
<tr>
<td>Blood pressure†</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hypertensive</td>
<td>6</td>
<td>3 to 10</td>
</tr>
<tr>
<td>Normotensive</td>
<td>28</td>
<td>24 to 33</td>
</tr>
<tr>
<td>Location‡</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lobar</td>
<td>31</td>
<td>25 to 37</td>
</tr>
<tr>
<td>Deep</td>
<td>11</td>
<td>6 to 18</td>
</tr>
<tr>
<td>Posterior fossa</td>
<td>37</td>
<td>23 to 54</td>
</tr>
</tbody>
</table>

*Data available for 4 studies including 249 patients.
†Data available for 6 studies including 382 patients.
‡Data available for 6 studies including 578 patients.
Type of Investigation

The radiological technique(s) used varied somewhat among the 8 cases (supplemental Table I, available online at http://stroke.ahajournals.org). The use of IADSA varied according to the characteristics of the patient, the location of the ICH, country, and specialty (supplemental Table II, available online at http://stroke.ahajournals.org). For example, in the nonhypertensive patient age 41 with lobar ICH (case 1), the proportion of respondents who did not perform IADSA at any stage was 27% overall, but this varied among countries (from 15% for France to 46% for the Netherlands) and specialists (from 41% for neurologists to 16% for neurosurgeons).

Despite the general agreement about the need for investigation of a patient age <45 years without a history of hypertension and with lobar ICH (case 1, the Figure), there were 33 different approaches to the number, order, and types of investigation used.

Table 2. Univariable Associations Expressed as Odds Ratios (95% CIs) of Patient Characteristics With Respondents’ Inclination to Investigate ICH Once, Twice, or 3 Times

<table>
<thead>
<tr>
<th>No. of Times Investigated</th>
<th>Younger Age*</th>
<th>No History of Pre-stroke Hypertension</th>
<th>Lobar Hematoma Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Once</td>
<td>16 (13 to 20)</td>
<td>5 (4 to 6)</td>
<td>2 (1 to 2)</td>
</tr>
<tr>
<td>Twice</td>
<td>9 (7 to 10)</td>
<td>3 (2 to 3)</td>
<td>2 (1 to 2)</td>
</tr>
<tr>
<td>3 Times</td>
<td>10 (8 to 12)</td>
<td>2 (2 to 3)</td>
<td>2 (1 to 2)</td>
</tr>
</tbody>
</table>

*Younger patients (age 38, 39, 41, and 43 years) vs older patients (age 72, 75, 80, and 83 years).

Timing of Investigation

Most first- and second-line investigations were performed within the first 3 months of ICH onset. There was a tendency to perform these investigations within 1 to 2 days in younger patients, with little apparent influence of hypertension and ICH location (supplemental Table I).

Discussion

In a systematic review of studies describing radiological investigations of ICH, we found selection biases and small sample sizes. In studies of the yield of IADSA, roughly one third of patients had an AVM or aneurysm, with a lower yield in patients with a history of hypertension or a deeply located ICH but an appreciable yield in older patients. However, in a survey of current practice, younger patient age strongly influenced whether further investigation of ICH was performed, followed by the absence of pre-stroke hypertension and lobar ICH location, which is in line with existing recommendations. Nevertheless, the types and timing of investigations varied considerably among specialties and countries.

Our systematic review benefited from a thorough search strategy, but the paucity of relevant studies and their variable quality precluded meta-analysis and firm conclusions. Our survey had several strengths. There were 617 responses, and the survey encompassed the 4 pertinent groups of specialists and 3 countries. The response rate was ~50%, which is quite good for surveys. However, the survey’s global coverage was...
limited by both logistical and resource constraints, so it has limited generalizability. To minimize the burden on respondents, we limited the survey to 8 cases, which inevitably curtailed our ability to explore the influence of patient age on investigation patterns and may have inflated the odds ratios in Table 2. Furthermore, the emphasis on radiological detection of structural abnormalities precluded an evaluation of the influence of radiological “surrogate markers” of small-vessel diseases (such as brain microbleeds, white matter hyperintensities, and lacunes). Since our literature search was conducted, several studies have described the diagnostic utility of CT angiography, compared with IADSA or surgical or pathological findings, and have confirmed that false-negatives and false-positives do occur with a frequency similar to those in the studies included in our systematic review.29–32

Because there have been few studies of the best diagnostic strategy for detection of a vascular malformation underlying ICH, firm recommendations for clinical practice are impossible.7,8 However, there is a risk of missing an underlying aneurysm or AVM in most patient and ICH subgroups if angiographic imaging is not performed (Table 1). Detection of an underlying AVM, aneurysm, dural arteriovenous fistula, or intracranial venous thrombosis is important because timely treatment can prevent recurrent ICH. Furthermore, delayed MRI may help identify an underlying tumor or cavernous malformation, Therefore, MRI and angiographic imaging seem worthwhile, depending on the patient’s clinical condition,3 but the availability and choice of these modalities will depend on local health care systems.

Despite the availability of a wide variety of imaging technologies for investigating ICH,2 the understanding of how to apply them in clinical practice is limited, resulting in variation among patients, countries, and specialties. Until further studies of the diagnostic accuracy of noninvasive investigations such as CT angiography or MRA have been performed, these techniques cannot replace IADSA for the investigation of ICH. Future research should also focus on the appropriate timing of investigation after ICH onset and the most parsimonious strategies for investigating patients at older ages and in resource-poor settings.

Acknowledgments
We are very grateful to Rosemary Anderson for administrative assistance, Aidan Hutchison for programming expertise, the professional organizations who shared their mailing lists for this survey (supplemental Figure III), and the members of these organizations who responded to the survey.

Sources of Funding
C.C. was funded by EA2691 and ADRNORD, and R.A.–S.S. was funded by the UK Medical Research Council. J.v.B. was funded by the Netherlands Organization for Scientific Research and the Netherlands Heart Foundation (grant No. 2002B138). C.J.M.K. was funded by a clinical fellowship from The Netherlands Organization for Health Research and Development (grant No. 907–00-103) and by a grant from the Netherlands Heart Association (grant No. 2007B1048).

Disclosures
None.

References


Table I. Types and Timing of Investigation for Those Respondents Who Decided to Investigate the 8 Cases of ICH

<table>
<thead>
<tr>
<th>Age, y</th>
<th>41</th>
<th>72</th>
<th>43</th>
<th>80</th>
<th>38</th>
<th>39</th>
<th>75</th>
<th>83</th>
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<tbody>
<tr>
<td>ICH location</td>
<td>Lobar</td>
<td>Lobar</td>
<td>Lobar</td>
<td>Lobar</td>
<td>Deep</td>
<td>Deep</td>
<td>Deep</td>
<td>Deep</td>
</tr>
<tr>
<td>Prestroke hypertension</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
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</table>

First investigation

<table>
<thead>
<tr>
<th>Investigation type</th>
<th>CT</th>
<th>MR</th>
<th>IADSA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>40 (35–43)</td>
<td>34 (31–38)</td>
<td>26 (23–30)</td>
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<tr>
<td>Location</td>
<td>22 (19–26)</td>
<td>66 (62–70)</td>
<td>12 (9–14)</td>
</tr>
<tr>
<td>ICH</td>
<td>18 (14–23)</td>
<td>53 (49–57)</td>
<td>22 (19–25)</td>
</tr>
<tr>
<td>Prestroke hypertension</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Investigation timing</td>
<td>23 (20–26)</td>
<td>49 (45–53)</td>
<td>28 (25–32)</td>
</tr>
<tr>
<td>1–2 d</td>
<td>27 (23–31)</td>
<td>55 (51–59)</td>
<td>20 (17–24)</td>
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<tr>
<td>1–3 mo</td>
<td>84 (78–89)</td>
<td>68 (64–72)</td>
<td>5 (3–7)</td>
</tr>
<tr>
<td>4–6 mo</td>
<td>16 (11–22)</td>
<td>67 (63–71)</td>
<td>0 (0–2)</td>
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Second investigation

<table>
<thead>
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<th>CT</th>
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<th>IADSA</th>
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<tbody>
<tr>
<td>Age (y)</td>
<td>5 (4–8)</td>
<td>46 (41–50)</td>
<td>49 (45–53)</td>
</tr>
<tr>
<td>Location</td>
<td>5 (3–8)</td>
<td>79 (74–83)</td>
<td>16 (12–21)</td>
</tr>
<tr>
<td>ICH</td>
<td>4 (2–11)</td>
<td>58 (53–63)</td>
<td>37 (32–41)</td>
</tr>
<tr>
<td>Prestroke hypertension</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Investigation timing</td>
<td>5 (3–8)</td>
<td>92 (83–95)</td>
<td>4 (2–11)</td>
</tr>
<tr>
<td>1–2 d</td>
<td>30 (26–34)</td>
<td>56 (52–60)</td>
<td>39 (35–44)</td>
</tr>
<tr>
<td>1–3 mo</td>
<td>15 (10–20)</td>
<td>64 (59–69)</td>
<td>12 (8–17)</td>
</tr>
<tr>
<td>4–6 mo</td>
<td>22 (12–38)</td>
<td>88 (75–96)</td>
<td>6 (1–18)</td>
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</table>

Third investigation

<table>
<thead>
<tr>
<th>Investigation type</th>
<th>CT</th>
<th>MR</th>
<th>IADSA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>2 (1–5)</td>
<td>60 (54–65)</td>
<td>38 (33–43)</td>
</tr>
<tr>
<td>Location</td>
<td>2 (1–5)</td>
<td>76 (65–83)</td>
<td>22 (15–32)</td>
</tr>
<tr>
<td>ICH</td>
<td>7 (1–30)</td>
<td>70 (63–75)</td>
<td>28 (23–35)</td>
</tr>
<tr>
<td>Prestroke hypertension</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Investigation timing</td>
<td>2 (1–5)</td>
<td>86 (62–96)</td>
<td>7 (1–30)</td>
</tr>
<tr>
<td>1–2 d</td>
<td>30 (26–34)</td>
<td>65 (59–71)</td>
<td>33 (27–39)</td>
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<td>1–3 mo</td>
<td>15 (10–20)</td>
<td>73 (64–80)</td>
<td>25 (18–34)</td>
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<tr>
<td>4–6 mo</td>
<td>22 (12–38)</td>
<td>74 (55–87)</td>
<td>22 (11–41)</td>
</tr>
</tbody>
</table>

Data are percentages of respondents (95% CIs). CT indicates CT angiography/venography; MR, plain MRI/angiography/venography.

Table II. Proportions (95% CIs) of Respondents Who Never Performed IADSA in All 8 Cases, by Specialty and Country

<table>
<thead>
<tr>
<th>Age, y</th>
<th>41</th>
<th>72</th>
<th>43</th>
<th>80</th>
<th>38</th>
<th>39</th>
<th>75</th>
<th>83</th>
</tr>
</thead>
<tbody>
<tr>
<td>ICH location</td>
<td>Lobar</td>
<td>Lobar</td>
<td>Lobar</td>
<td>Lobar</td>
<td>Deep</td>
<td>Deep</td>
<td>Deep</td>
<td>Deep</td>
</tr>
<tr>
<td>Prestroke hypertension</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>

| Overall | 27 (24–31) | 79 (75–82) | 47 (44–52) | 96 (93–98) | 37 (33–41) | 67 (63–71) | 90 (87–92) | 99 (96–100) |

By specialty

| Neurologists | 41 (33–50) | 85 (77–90) | 54 (45–63) | 97 (89–99) | 48 (39–57) | 64 (54–72) | 91 (83–95) | 97 (86–100) |
| Stroke specialists | 37 (30–44) | 94 (89–97) | 56 (49–63) | 100 (96–100) | 47 (40–55) | 74 (66–80) | 98 (93–99) | 100 (93–100) |
| Neurosurgeons | 16 (11–23) | 67 (59–74) | 48 (40–56) | 93 (83–97) | 24 (18–31) | 65 (57–73) | 83 (75–89) | 97 (86–100) |
| Neuroradiologists | 16 (11–23) | 69 (61–76) | 30 (23–38) | 94 (87–97) | 29 (22–36) | 64 (56–72) | 86 (79–91) | 100 (94–100) |

By country

| United Kingdom | 33 (27–39) | 78 (71–83) | 51 (44–57) | 96 (88–99) | 33 (27–40) | 64 (57–70) | 85 (78–90) | 96 (88–99) |
| Netherlands | 46 (37–55) | 86 (72–92) | 69 (59–77) | 98 (87–100) | 59 (50–68) | 90 (82–95) | 86 (76–92) | 100 (84–100) |
CASE 1

A 41-year-old lawyer presents with sudden headache, nausea, vomiting and a secondarily generalised seizure. She has no past medical history, is not known to be hypertensive, and was previously independent. On examination, she has a Glasgow Coma Score of 14 (E4 V4 M6) and a right homonymous upper quadrantanopia. Her blood pressure is 155/80. Her unenhanced brain CT, performed the next day when her clinical state is the same, is shown opposite.

1 What is the location of this hemorrhage? Lobar or Deep

Assuming her clinical state remains unchanged...

2 In this case, would you request further imaging to identify an underlying cause of the hemorrhage?

Yes or No Go to case 2

3a What type of imaging? [tick one box]

- CT angiography
- CT venography
- MRI brain
- MRI brain + MR angiography
- MRI brain + MR venography
- Catheter angiography

3b How long after the initial bleed? [tick one box]

- Within a day or two
- 1 month
- 2 months
- 3 months
- 4 months
- 6 months

If the investigation you selected is normal, and her clinical state improves or remains the same...

4 In this case, would you request further imaging to identify an underlying cause of the hemorrhage?

Yes or No Go to case 2

5a What type of imaging? [tick one box]

- CT angiography
- CT venography
- MRI brain
- MRI brain + MR angiography
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- Catheter angiography

5b How long after the initial bleed? [tick one box]

- Within a day or two
- 1 month
- 2 months
- 3 months
- 4 months
- 6 months

If the investigation you selected is normal again, & her state improves or remains the same...

6 In this case, would you request further imaging to identify an underlying cause of the hemorrhage?

Yes or No Go to case 2

7a What type of imaging? [tick one box]

- CT angiography
- CT venography
- MRI brain
- MRI brain + MR angiography
- MRI brain + MR venography
- Catheter angiography

7b How long after the initial bleed? [tick one box]

- Within a day or two
- 1 month
- 2 months
- 3 months
- 4 months
- 6 months

Figure I. Literature search strategy.

Figure II. Survey questionnaire.
CASE 2
A 72 year-old retired dentist presents with a sudden right hemiparesis. He has no past medical history, is not known to be hypertensive, and was previously independent.

On examination, he has a Glasgow Coma Score of 13 (E4 V4 M5, mild dysphasia and a right hemiparesis. His blood pressure is 160/80.

His unenhanced brain CT, performed the next day when his clinical state is the same, is shown opposite.

TABLE 1

<table>
<thead>
<tr>
<th>Question</th>
<th>Yes</th>
<th>No</th>
<th>Go to case 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1  What is the location of this hemorrhage?</td>
<td>Lobar</td>
<td>Deep</td>
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<td>2  Assuming his clinical state remains unchanged...</td>
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<td>3a What type of imaging? (tick one box)</td>
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<td>4 In this case, would you request further imaging to identify an underlying cause of the hemorrhage?</td>
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Figure II (Continued).
CASE 3
A 43 year-old taxi driver presents with sudden headache, and nausea. He has a past medical history of hypertension treated with an ACE-inhibitor, lowering his BP to around 140/80. He was previously independent.
On examination, he has a Glasgow Coma Score of 14 (E4 V4 M6) and a slight dysphasia. His BP is 165/85.
His unenhanced brain CT, performed the next day when his clinical state is the same, is shown opposite.

1 What is the location of this hemorrhage? Lobar or Deep

Assuming his clinical state remains unchanged...

2 In this case, would you request further imaging to identify an underlying cause of the hemorrhage?
Yes or No

3a What type of imaging? [tick one box]
- CT angiography
- CT venography
- MRI brain
- MRI brain + MR angiography
- MRI brain + MR venography
- Catheter angiography

3b How long after the initial bleed? [tick one box]
- Within a day or two
- 1 month
- 2 months
- 3 months
- 4 months
- 6 months

If the investigation you selected is normal, and his clinical state improves or remains the same...

4 In this case, would you request further imaging to identify an underlying cause of the hemorrhage?
Yes or No

5a What type of imaging? [tick one box]
- CT angiography
- CT venography
- MRI brain
- MRI brain + MR angiography
- MRI brain + MR venography
- Catheter angiography

5b How long after the initial bleed? [tick one box]
- Within a day or two
- 1 month
- 2 months
- 3 months
- 4 months
- 6 months

If the investigation you selected is normal again, and his state improves or remains the same...

6 In this case, would you request further imaging to identify an underlying cause of the hemorrhage?
Yes or No

7a What type of imaging? [tick one box]
- CT angiography
- CT venography
- MRI brain
- MRI brain + MR angiography
- MRI brain + MR venography
- Catheter angiography

7b How long after the initial bleed? [tick one box]
- Within a day or two
- 1 month
- 2 months
- 3 months
- 4 months
- 6 months

Figure II (Continued).
CASE 4

An 80 year-old widow presents with sudden headache, nausea, and a generalised seizure. She has a past history of osteoarthritis and hypertension treated with diuretics. Her usual BP is 135/75. She was previously independent.

On examination, she has a Glasgow Coma Score of 13 (E4 V4 M5) and a weak right arm. Her BP is 170/90.

Her unenhanced brain CT, performed the next day when her clinical state is the same, is shown opposite.

1 What is the location of this hemorrhage? Lobar or Deep

• Assuming her clinical state remains unchanged...

2 In this case, would you request further imaging to identify an underlying cause of the hemorrhage? Yes or No → Go to case 5

3a What type of imaging? [tick one box]
   - CT angiography
   - CT venography
   - MRI brain
   - MRI brain + MR angiography
   - MRI brain + MR venography
   - Catheter angiography

3b How long after the initial bleed? [tick one box]
   - Within a day or two
   - 1 month
   - 2 months
   - 3 months
   - 4 months
   - 6 months

• If the investigation you selected is normal, and her clinical state improves or remains the same...

4 In this case, would you request further imaging to identify an underlying cause of the hemorrhage? Yes or No → Go to case 5

5a What type of imaging? [tick one box]
   - CT angiography
   - CT venography
   - MRI brain
   - MRI brain + MR angiography
   - MRI brain + MR venography
   - Catheter angiography

5b How long after the initial bleed? [tick one box]
   - Within a day or two
   - 1 month
   - 2 months
   - 3 months
   - 4 months
   - 6 months

• If the investigation you selected is normal again, and her state improves or remains the same...

6 In this case, would you request further imaging to identify an underlying cause of the hemorrhage? Yes or No → Go to case 5

7a What type of imaging? [tick one box]
   - CT angiography
   - CT venography
   - MRI brain
   - MRI brain + MR angiography
   - MRI brain + MR venography
   - Catheter angiography

7b How long after the initial bleed? [tick one box]
   - Within a day or two
   - 1 month
   - 2 months
   - 3 months
   - 4 months
   - 6 months

Figure II (Continued).
CASE 5

A 38 year-old housewife presents with gradual headache, profuse vomiting, and weakness of the right face, arm and leg. She has no past medical history, is not known to be hypertensive, and was previously independent.

On examination, she has a Glasgow Coma Score of 12 (E3 V3 M6) with a right hemiplegia and dysphasia. Her blood pressure is 165/95.

Her unenhanced brain CT, performed immediately, is shown. Her GCS improves to E4 V4 M6 the next day.

1. What is the location of this hemorrhage?  
   - Lobar  
   - Deep

   **Assuming her clinical state remains unchanged...**

2. In this case, would you request further imaging to identify an underlying cause of the hemorrhage?  
   - Yes  
   - No

   **3a** What type of imaging? [tick one box]  
   - CT angiography  
   - CT venography  
   - MRI brain  
   - MRI brain + MR angiography  
   - MRI brain + MR venography  
   - Catheter angiography

   **3b** How long after the initial bleed? [tick one box]  
   - Within a day or two  
   - 1 month  
   - 2 months  
   - 3 months  
   - 4 months  
   - 6 months

   ► If the investigation you selected is normal, and her clinical state improves or remains the same...

4. In this case, would you request further imaging to identify an underlying cause of the hemorrhage?  
   - Yes  
   - No

   **5a** What type of imaging? [tick one box]  
   - CT angiography  
   - CT venography  
   - MRI brain  
   - MRI brain + MR angiography  
   - MRI brain + MR venography  
   - Catheter angiography

   **5b** How long after the initial bleed? [tick one box]  
   - Within a day or two  
   - 1 month  
   - 2 months  
   - 3 months  
   - 4 months  
   - 6 months

   ► If the investigation you selected is normal again, and her state improves or remains the same...

6. In this case, would you request further imaging to identify an underlying cause of the hemorrhage?  
   - Yes  
   - No

   **7a** What type of imaging? [tick one box]  
   - CT angiography  
   - CT venography  
   - MRI brain  
   - MRI brain + MR angiography  
   - MRI brain + MR venography  
   - Catheter angiography

   **7b** How long after the initial bleed? [tick one box]  
   - Within a day or two  
   - 1 month  
   - 2 months  
   - 3 months  
   - 4 months  
   - 6 months

Figure II (Continued).
CASE 6
A 39 year-old labourer presents with sudden right hemiparesis. He has a past history of hypertension treated with beta blockers. His BP is usually around 140/90. He was previously independent.

On examination, he has a Glasgow Coma Score of 14 (E4 V5 M5) and a right hemiparesis. His blood pressure is 185/97.

His unenhanced brain CT, performed the next day when his clinical state is the same, is shown opposite.

1 What is the location of this hemorrhage? Lobar or Deep

► Assuming his clinical state remains unchanged...

2 In this case, would you request further imaging to identify an underlying cause of the hemorrhage? Yes or No ➔ Go to case 7

3a What type of imaging? [tick one box] 3b How long after the initial bleed? [tick one box]
- CT angiography
- CT venography
- MRI brain
- MRI brain + MR angiography
- MRI brain + MR venography
- Catheter angiography
- Within a day or two
- 1 month
- 2 months
- 3 months
- 4 months
- 6 months

► If the investigation you selected is normal, and his clinical state improves or remains the same...

4 In this case, would you request further imaging to identify an underlying cause of the hemorrhage? Yes or No ➔ Go to case 7

5a What type of imaging? [tick one box] 5b How long after the initial bleed? [tick one box]
- CT angiography
- CT venography
- MRI brain
- MRI brain + MR angiography
- MRI brain + MR venography
- Catheter angiography
- Within a day or two
- 1 month
- 2 months
- 3 months
- 4 months
- 6 months

► If the investigation you selected is normal again, and his state improves or remains the same...

6 In this case, would you request further imaging to identify an underlying cause of the hemorrhage? Yes or No ➔ Go to case 7

7a What type of imaging? [tick one box] 7b How long after the initial bleed? [tick one box]
- CT angiography
- CT venography
- MRI brain
- MRI brain + MR angiography
- MRI brain + MR venography
- Catheter angiography
- Within a day or two
- 1 month
- 2 months
- 3 months
- 4 months
- 6 months

Figure II (Continued).
CASE 7

A 75-year old retired postman presents with sudden confusion, nausea, and mild left face and arm weakness. He has no past medical history, is not known to be hypertensive, and was independent.

On examination, he has a Glasgow Coma Score of 14 (E4 V5 M5) and mild left face and arm weakness. His blood pressure is 165/95.

His unenhanced brain CT, performed the next day when his clinical state is the same, is shown opposite.

1. What is the location of this hemorrhage?
   - Lobar
   - Deep

   ► Assuming his clinical state remains unchanged...

   2. In this case, would you request further imaging to identify an underlying cause of the hemorrhage?
      - Yes
      - No

   3a. What type of imaging? [tick one box]
      - CT angiography
      - CT venography
      - MRI brain
      - MRI brain + MR angiography
      - MRI brain + MR venography
      - Catheter angiography

   3b. How long after the initial bleed? [tick one box]
      - Within a day or two
      - 1 month
      - 2 months
      - 3 months
      - 4 months
      - 6 months

   ► If the investigation you selected is normal, and his clinical state improves or remains the same...

   4. In this case, would you request further imaging to identify an underlying cause of the hemorrhage?
      - Yes
      - No

   5a. What type of imaging? [tick one box]
      - CT angiography
      - CT venography
      - MRI brain
      - MRI brain + MR angiography
      - MRI brain + MR venography
      - Catheter angiography

   5b. How long after the initial bleed? [tick one box]
      - Within a day or two
      - 1 month
      - 2 months
      - 3 months
      - 4 months
      - 6 months

   ► If the investigation you selected is normal again, and his state improves or remains the same...

   6. In this case, would you request further imaging to identify an underlying cause of the hemorrhage?
      - Yes
      - No

   7a. What type of imaging? [tick one box]
      - CT angiography
      - CT venography
      - MRI brain
      - MRI brain + MR angiography
      - MRI brain + MR venography
      - Catheter angiography

   7b. How long after the initial bleed? [tick one box]
      - Within a day or two
      - 1 month
      - 2 months
      - 3 months
      - 4 months
      - 6 months

   Figure II (Continued).
CASE 8

An 83 year-old woman presents with sudden headache. She has a past history of hypertension treated with a diuretic. Her BP is usually around 145/75. She was previously independent.

On examination, she has a Glasgow Coma Score of 15 (E4 V5 M6), right-sided dysaesthesia and hemisensory impairment. Her blood pressure is 155/80.

Her unenhanced brain CT, performed the next day when her clinical state is the same, is shown opposite.

1 What is the location of this hemorrhage? [tick one box]

- Lobar
- Deep

2 Assuming her clinical state remains unchanged...

- In this case, would you request further imaging to identify an underlying cause of the hemorrhage?

- Yes
- No

3a What type of imaging? [tick one box]

- CT angiography
- CT venography
- MRI brain
- MRI brain + MR angiography
- MRI brain + MR venography
- Catheter angiography

3b How long after the initial bleed? [tick one box]

- Within a day or two
- 1 month
- 2 months
- 3 months
- 4 months
- 6 months

4 In this case, would you request further imaging to identify an underlying cause of the hemorrhage?

- Yes
- No

5a What type of imaging? [tick one box]

- CT angiography
- CT venography
- MRI brain
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- Catheter angiography

5b How long after the initial bleed? [tick one box]

- Within a day or two
- 1 month
- 2 months
- 3 months
- 4 months
- 6 months

5 If the investigation you selected is normal, and her clinical state improves or remains the same...

6 In this case, would you request further imaging to identify an underlying cause of the hemorrhage?

- Yes
- No

7a What type of imaging? [tick one box]

- CT angiography
- CT venography
- MRI brain
- MRI brain + MR angiography
- MRI brain + MR venography
- Catheter angiography

7b How long after the initial bleed? [tick one box]

- Within a day or two
- 1 month
- 2 months
- 3 months
- 4 months
- 6 months

Figure II (Continued).
United Kingdom

- **Neurologists:** Association of British Neurologists (www.theabn.org)
- **Neuroradiologists:** British Society of Neuroradiologists (www.bsnr.co.uk)
- **Neurosurgeons:** Society of British Neurological Surgeons (www.sbns.org.uk)
- **Stroke specialists:** British Association of Stroke Physicians (www.basp.ac.uk)

France

- **Neurologists:** Collège National des Neurologues des Hôpitaux Généraux (www.cnngen.fr)
- **Neuroradiologists:** Société Française de NeuroRadiologie (www.sfnr.net)
- **Neurosurgeons:** Société Française de NeuroChirurgie (www2.neurochirurgie.fr)
- **Stroke specialists:** Société Française Neuro-Vasculaire (www.sfnv-france.com)

The Netherlands

- **Neurologists:** Nederlandse Vereniging voor Neurologie (www.neurologie.nl)
- **Neuroradiologists:** Nederlandse Vereniging voor Radiologie, sectie Neuroradiologie (www.radiologen.nl)
- **Neurosurgeons:** Nederlandse Vereniging van Neurochirurgen (www.nvvn.org)
- **Stroke specialists:** Nederlandse Neurovasculaire Werkgroep (www.neurologie.nl/nnw2)
Figure VI. Numbers and proportions of responders to all eight cases who would perform one (black), two (gray), or three (white) further investigations, subdivided by speciality.
Radiological Investigation of Spontaneous Intracerebral Hemorrhage. Systematic Review and Trinational Survey
Charlotte Cordonnier, Catharina J.M. Klijn, Janneke van Beijnum and Rustam Al-Shahi Salman

Stroke. published online February 18, 2010;
Stroke is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
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Print ISSN: 0039-2499. Online ISSN: 1524-4628

The online version of this article, along with updated information and services, is located on the World Wide Web at:
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