Clinical features of primary brain tumours:
a case–control study using electronic primary care records

William Hamilton and David Kernick

INTRODUCTION
Primary brain tumours account for around 2% of all new tumours in the UK, with over 4500 new diagnoses each year and an overall annual incidence of 7 per 100,000. They are more common in males and with increasing age. Most malignant brain tumours are fatal, but slower-growing tumours may allow survival for some years. Approximately 30% of tumours are benign, the most common being meningiomas. Other rarer tumours arise from local cell types, such as the pituitary or acoustic nerve. Secondary brain tumours are more common than primary ones, but in most patients the primary cancer has already been diagnosed, although a small proportion of patients first present with cerebral metastases.¹

The symptoms of primary brain tumours have only been described in secondary care series. These have been mainly retrospective studies with a potential for recall bias. Up to 70% of patients have a headache during the course of their illness, particularly in the final stages of their disease; however, this is broadly the same as the population incidence of headache.² The incidence of headache at the time of diagnosis is between 23% and 56%; however, all these figures vary with the clinical setting, and may have been affected by recall bias.²⁻⁴ Headache as a first and isolated presentation of brain tumours is much rarer: it is reported in 2–16% of patients.⁵⁻⁶

Epilepsy is also a feature of some brain tumours, particularly in younger patients, and may precede
How this fits in

Brain tumours are rare, and very few primary care clinicians gain experience in their diagnosis. Several symptoms have been described from secondary care series, but no research has examined symptom reporting in primary care. This study describes the symptoms recorded in primary care notes before brain tumours were diagnosed. Although headache was one of the symptoms associated with brain tumours, the risk of an underlying tumour was very small. This supports clinicians who deem brain scanning unnecessary for uncomplicated headache.

Data are subject to thorough validation and stringent quality checks. Electronic records in the GPRD are regarded as high quality, and the database has been used in many epidemiological research studies.

Identification of cases and controls

A list of 112 brain tumour codes was assembled from the library of codes and categorised into benign ($n = 27$, mostly meningiomas) and malignant tumours ($n = 85$). One code read simply ‘brain tumour.’ Tumours with this code were assumed to be malignant, unless subsequent records contained only benign tumour codes. GPRD staff identified all 3549 patients aged 18 years or over with a brain tumour diagnosed between May 1988 and March 2006, and with at least 2 years of data before the first tumour code (the index date). For each case, all potential controls matched to the same practice and sex, and within 1 year of age of the case were identified: seven were selected from these using a computer-generated random sequence.

Cases and controls were only used if they had consulted at least once in the 6 months before the index date. This eliminated any patients erroneously registered with the participating practices (so-called ‘ghosts’) and also allowed calculation of positive predictive values (PPVs) for patients who actually consulted in primary care. Controls were excluded if they previously had a brain tumour.

Selection of clinical features likely to predict primary tumour

Libraries of codes for clinical variables previously described with brain tumours were assembled (Box 1). Occurrences of these variables in the 6 months before the index date in cases and controls were identified. Variables were retained only if they occurred in at least 1% of cases or controls (in practice, this was always cases). Re-consultations with the same symptom were also retained if the subsequent symptom was also present in 1% or more cases or controls. No restriction was placed on reporting of the variable before the 6 month period of study, except for seizures which were only used if the patient had no previous seizure or anticonvulsant therapy code in their records.

Identification of independent associations with tumours

Differences between cases and controls were analysed using conditional logistic regression. Variables associated with tumours in univariable analyses with $P \leq 0.1$ were entered into the multivariable analyses. This was performed in stages, first collecting similar variables together, such as those that could represent weakness. Using this approach, a final model was derived including all the variables independently associated with brain tumours.

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Box 1. Clinical features selected for study.

- Symptoms
  - Confusion, headache, weakness, anxiety, depression, fatigue, vertigo, smoking, excess alcohol intake, personality change, memory loss, and disorders of smell or vision.
- Examination findings
  - Motor loss, sensory loss, papilloedema, and abnormal visual fields.
- Diagnostic labels
  - New-onset seizure, migraine, and upper respiratory tract infections.
discarded variables were checked against the final model. Seven clinically plausible internal interactions were tested in the final model. Differences in variable reporting between benign and malignant tumours were tested by adding interaction terms between benign/malignant status and each variable, and assessing for significance by likelihood ratio testing.

**Calculation of positive predictive values**

PPV calculation was possible because all cases reported in the GPRD had been identified. PPVs for individual variables and for pairs of variables were calculated from likelihood ratio and the observed incidence of cancer during the study. As four of 3459 cases and 6830 of 24021 initially-selected controls had not consulted in primary care, PPVs were divided by 0.715 to give predictive values for the consulting population. Stratified analyses by 10-year age bands were performed for individual features, but these were not performed if any cell in the 2×2 table was <10.

Sample size calculations used an estimated 3500 cases. With this number, seven controls provided >99% power to identify a change in a rare variable from 1% prevalence in one group to 2% in the other, using a two-sided 5% α level. Analyses were performed using Stata (version 9).

**RESULTS**

After application of the exclusion criteria, the number of cases available for study was reduced from 3549 to 3505. Four cases had not consulted in primary care in the 6 months before diagnosis, and a further 40 cases had no matched controls who had consulted. The number of controls fell from 24824 to 17173. Of these, 803 were already in the study as cases (772 had been selected as a control for themselves, and 31 as a control for another case); 6830 had not consulted; and 18 were consulting controls to the four non-consulting cases. Of the 3505 cases, 2397 were recorded as a brain tumour, and 1108 were recorded as a meningioma, and 18 were recorded as benign/malignant status and each variable, and assessing for significance by likelihood ratio testing.

**Table 1. Demographics and incidence of brain tumours.**

<table>
<thead>
<tr>
<th>Age, years</th>
<th>Tumours, n</th>
<th>Malignant tumours, n</th>
<th>Females, n (%)</th>
<th>Person years in GPRD (n x 100 000)</th>
<th>Incidence of tumours*</th>
<th>Incidence of malignant tumours*</th>
</tr>
</thead>
<tbody>
<tr>
<td>18–29</td>
<td>159</td>
<td>134</td>
<td>71 (45)</td>
<td>51.4</td>
<td>3.1</td>
<td>2.6</td>
</tr>
<tr>
<td>30–39</td>
<td>276</td>
<td>206</td>
<td>137 (50)</td>
<td>52.8</td>
<td>5.2</td>
<td>3.9</td>
</tr>
<tr>
<td>40–49</td>
<td>432</td>
<td>280</td>
<td>227 (53)</td>
<td>48.6</td>
<td>8.9</td>
<td>5.7</td>
</tr>
<tr>
<td>50–59</td>
<td>675</td>
<td>471</td>
<td>361 (53)</td>
<td>42.4</td>
<td>15.9</td>
<td>11.1</td>
</tr>
<tr>
<td>60–69</td>
<td>822</td>
<td>584</td>
<td>410 (50)</td>
<td>32.5</td>
<td>25.3</td>
<td>18.0</td>
</tr>
<tr>
<td>70–79</td>
<td>767</td>
<td>511</td>
<td>419 (53)</td>
<td>24.8</td>
<td>30.9</td>
<td>20.6</td>
</tr>
<tr>
<td>80–89</td>
<td>339</td>
<td>191</td>
<td>198 (58)</td>
<td>12.4</td>
<td>27.3</td>
<td>15.4</td>
</tr>
<tr>
<td>&gt;90</td>
<td>35</td>
<td>20</td>
<td>21 (60)</td>
<td>2.4</td>
<td>14.6</td>
<td>8.3</td>
</tr>
<tr>
<td>Total</td>
<td>3505</td>
<td>2397</td>
<td>1844 (53)</td>
<td>267.3</td>
<td>13.1</td>
<td>9.0</td>
</tr>
</tbody>
</table>

GPRD = General Practice Research Database. *Incidence per 100 000 per year.

**Table 2. Frequency of clinical features in cases and controls.**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Cases, n (%)</th>
<th>Controls, n (%)</th>
<th>LR (95% CI)</th>
<th>PPV* (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Headache</td>
<td>362 (10.2)</td>
<td>261 (2.6)</td>
<td>6.9 (6.2 to 7.1)</td>
<td>0.09% (0.08 to 0.10)</td>
</tr>
<tr>
<td>Motor loss</td>
<td>308 (8.7)</td>
<td>731 (3.1)</td>
<td>21. (1.9 to 2.4)</td>
<td>0.026% (0.024 to 0.030)</td>
</tr>
<tr>
<td>New-onset seizure</td>
<td>154 (4.4)</td>
<td>48 (0.05)</td>
<td>96 (81 to 110)</td>
<td>1.2% (1.0 to 1.4)</td>
</tr>
<tr>
<td>Confusion</td>
<td>109 (3.1)</td>
<td>47 (0.2)</td>
<td>16 (13 to 19)</td>
<td>0.20% (0.16 to 0.24)</td>
</tr>
<tr>
<td>Weakness</td>
<td>95 (2.7)</td>
<td>42 (0.2)</td>
<td>11 (9.1 to 14)</td>
<td>0.14% (0.11 to 0.18)</td>
</tr>
<tr>
<td>Memory loss</td>
<td>37 (1.1)</td>
<td>64 (0.4)</td>
<td>2.9 (2.0 to 4.1)</td>
<td>0.036% (0.026 to 0.052)</td>
</tr>
<tr>
<td>Visual disorder</td>
<td>35 (1.0)</td>
<td>62 (0.3)</td>
<td>2.8 (2.0 to 4.1)</td>
<td>0.035% (0.025 to 0.051)</td>
</tr>
</tbody>
</table>

LR = likelihood ratio. *Positive predictive value in the consulting population.
DISCUSSION

Summary of main findings
This is the first study of the features of brain tumours from primary care. Most of the symptoms reported from secondary care series were highly significantly associated with cancer, both in univariable and in multivariable analyses. However, the risk of a brain tumour with each of the symptoms was very low, reflecting the low overall incidence of tumours. This explains the relatively high ORs in Table 3 (which show strong associations between symptoms and diagnosis of brain tumour), yet small PPVs in Table 2 (which reflect the strength of the association between the symptom and having a tumour, plus the background incidence of brain tumours). The exception to this was new-onset epilepsy, which had an overall risk of 1.2%, rising to 2.3% if the patient was >60 years of age. In contrast, the risk with headache presented to primary care was less than 1 in 1000. Even when a second symptom was present, the risk of a brain tumour only rose to 3.9 in 1000.

Strengths and limitations of the study
It is not known how accurate the tumour diagnoses were, but it is unlikely that such a serious diagnosis would be entered erroneously more than a few times. The incidence of malignant tumours is similar to the 2002 incidence in the UK, although without the male preponderance. Some tumours were not classified as benign or malignant: a distinction that is less meaningful in relation to brain tumours than other tumours (a ‘benign’ brain tumour may cause death; a malignant brain tumour rarely, if ever, metastasizes).

For the primary care clinician, this is not as important as it seems (although very important for the patient), as generalists will wish to identify all brain tumours, whatever their level of malignancy, and refer for further investigation.

The major limitation of the study is that it relies on doctors recording symptoms as well as diagnoses. It has always been a requirement of participation in the GPRD that diagnoses are recorded for every consultation. Symptom recording may not be as systematic, especially in the earlier years of the GPRD, when many practices maintained parallel written records. Furthermore, some of the variables studied are rather crude, reflecting the data source; for example, the headache code encompassed several different codes, and omitted potentially important factors, such as duration, type, and severity.

GPs would routinely use these parameters in their assessments of the possibility of an underlying tumour. Under-recording of symptoms or signs may have meant that some features that are genuinely associated with brain tumours, such as papilloedema, were not identified in this study. For the calculation of PPVs, under-recording is less of a concern. PPV is derived from the likelihood ratio and the incidence; the latter is unlikely to be significantly subject to recording bias (especially as the incidence rates in this study were so close to published national rates).

Likelihood ratios would be misleading if under-recording was systematically more prevalent in either cases or controls. There is no particular reason why this should be so, although it is possible that a spell of undiagnosed ill-health in cases before their diagnosis could lead to better symptom recording (and thus overestimation of PPVs).

Comparison with existing literature
The prevalence of most features in cases was lower than in previous studies, except for the 10.2% with headache, which is similar to previous estimates of 2–16% reporting headache as an isolated initial symptom. This is not surprising for two reasons. The first is the possibility of under-recording, as discussed above; the second is that the symptoms had to be deemed important enough for patients to have consulted their doctor. This is a much higher threshold than applied in previous studies where patients with a tumour were asked about their symptoms retrospectively. As the clinical problem of how and whom to select for further investigation is stationed in the consulting room (not in the population as a whole), it is appropriate to use data derived from the consulting room.

Implications for clinical practice and future research
Headache was strongly associated with primary brain tumours, yet the PPV was extremely small, at less than 1 in 1000. Even when there was a second symptom, such as confusion, the PPV only approached 3.9 in 1000. This is very reassuring, and provides support to doctors who may feel pressured.

<table>
<thead>
<tr>
<th>Variable</th>
<th>OR (95% CI)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Symptoms</td>
<td></td>
<td></td>
</tr>
<tr>
<td>New-onset seizure</td>
<td>87.0 (42.0 to 180.0)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Weakness</td>
<td>23.0 (7.1 to 77.0)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Headache</td>
<td>6.7 (5.6 to 8.0)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Confusion</td>
<td>11.0 (7.6 to 16.0)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Memory loss</td>
<td>2.7 (1.7 to 4.2)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Visual disorder</td>
<td>2.0 (1.2 to 3.3)</td>
<td>0.005</td>
</tr>
<tr>
<td>Physical sign</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Motor loss</td>
<td>1.8 (1.5 to 2.2)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Interaction term</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Motor loss with weakness</td>
<td>0.2 (0.06 to 0.8)</td>
<td>0.025</td>
</tr>
</tbody>
</table>

OR = odds ratio.
into referral. In contrast, the risk from seizures was much higher, at 1.2% overall for new-onset seizures reported to primary care, rising to 2.3% if the patient was >60 years of age. This compares with tertiary care figures of 6–7%. The difference probably reflects the population being studied, in that hospital attenders are a selected population, even with such a dramatic event as a first seizure.

The study used a robust definition of a first seizure: patients so labelled had no previous anticonvulsant therapy or seizure recorded. This may not have been the case for hospital-based studies. Another possibility is misdiagnosis of seizures, as approximately a quarter of epilepsy is misdiagnosed, particularly by generalists. Assuming misdiagnosis occurred mainly in the control group, the PPVs in this study may be underestimated by a quarter. Nonetheless, 1.2% (or a quarter higher) is still an appreciable risk, and brings into question recent UK guidance about neuroimaging in epilepsy. The recommendation that patients with idiopathic epilepsy need not have a brain scan is, to an extent, a circular argument, as it is difficult to label the epilepsy idiopathic without a negative scan. In practice, most neurologists perform a scan on all patients with new seizures. The results suggest that they are right to do so, even though a very high percentage will not show a tumour.

The other symptoms — confusion, weakness, motor loss, memory loss, and visual disorder — were each independently associated with brain tumours, but were individually of very low risk. All these features would prompt the generalist to do a neurological examination, including looking for papilloedema. Both motor loss and memory loss would generally lead to neuroimaging (scanning in motor loss looking primarily for a stroke; and in memory loss, seeking alternatives to Alzheimer’s disease, such as hydrocephalus). The remaining three symptoms would rarely lead to imaging if they were isolated; results suggest that this is reasonable practice.

Overall, the results are reassuring. The incidence of primary brain tumours in primary care is very low. Several features are linked with tumours, but all of them are much more commonly caused by a different condition. The results suggest that neuroimaging is appropriate for all new-onset epilepsy, but is unnecessary in patients with isolated headache at presentation. Even with a dataset as large as the GPRD, it was impossible to identify specific second symptoms accompanying headache that would change this recommendation. This may require a prospective study of headache, but such a study would have to be extremely large to overcome the rarity of brain tumours.

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**Ethics committee**

Scientific and Ethical Advisory Group of the GPRD (reference number 784R)

**Competing interests**

David Kernick chairs the British Association for the Study of Headache. This body receives educational support from individual pharmaceutical companies. No company had any input of any nature into this study or paper.

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**REFERENCES**