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Mortality in the Denbighshire Parkinson's disease community cohort at 18-years.

Journal:	<i>BMJ Open</i>
Manuscript ID	bmjopen-2017-018969
Article Type:	Research
Date Submitted by the Author:	02-Aug-2017
Complete List of Authors:	Hobson, Peter; Academic Unit Meara, Jolyon; Academic Unit
Primary Subject Heading:	Neurology
Secondary Subject Heading:	Epidemiology
Keywords:	Parkinson-s disease < NEUROLOGY, EPIDEMIOLOGY, Dementia < NEUROLOGY

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Mortality in the Denbighshire Parkinson's disease community cohort at 18-years.

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Keywords:

Word count: 3267

Abstract

Objective: To examine the reported causes of death in a community cohort of Parkinson's disease (PD) patients.

Setting and participants: A total of 166 PD patients and 102 controls were included in this investigation. Hospital and primary care records were employed to ascertain the number of individuals who died during the investigation period. The primary and underlying cause of death was extracted from certificates obtained from the United Kingdom General Register Office.

Results: There were 158 (95%) deaths in the PD and 34 (33%) deaths recorded in the control cohort. The Standard Mortality Rate (SMR) was 1.82 (95% CI: 1.55 – 2.13). Controlling for prevalent PD cases at baseline (n =80), the SMR was 1.72 (95% CI: 1.36 – 2.17), indicating that there was no excess mortality between the prevalent and incident cases ($p < 0.186$). The main cause of death reported in the PD cohort was pneumonia (52%), followed by cardiac related deaths (21%). PD as the primary or underlying cause was not reported in 75/158 (47%) of the cohort. In addition, although 144 of the cohort had a diagnosis of dementia, this was reported in less than 10% (n=14) of their death certificates.

Conclusion: This community based investigation established that PD is associated with a higher risk of mortality compared to the general population. In addition, we found that the majority of patients with PD if they survive long enough will develop dementia. However, the reporting of PD and dementia as a cause or underlying cause of death on certificates was found to be suboptimal. The results from this investigation suggest that use of mortality statistics alone in epidemiological studies, healthcare planning and provision need to be reconsidered, because they are not a valid or reliable source of data capture.

Strengths and limitations

- Community based longitudinal follow-up cohort design
- All patients fulfilled diagnostic criteria for Parkinson's disease and or dementia.
- Baseline and subsequent repeat measure data capture allowed analysis for predictive outcomes.
- Prevalent and incident cases of Parkinson's disease were included in the cohort, although this was controlled for in the analysis.
- Control cohort included subjects without known neurological condition and thus may have intruded bias in the outcome comparisons with the Parkinson's disease patients.

Introduction

Data drawn from death certificates is often employed by epidemiological, public health and research scientists to capture the incidence, prevalence and mortality in populations. In addition, these statistics are often utilized in the evaluation of public health interventions, setting priorities for medical research and health services, the planning of health services, and the clinical assessment of the effectiveness of those services. [1-3] The introduction of the revised International Classification of Diseases (ICD) system in 2001 aim was to improve the accuracy in the reported cause of death, where underlying conditions, mentioned in Part 1 or 2 of death certification take priority over others. [4,5] The underlying principle for this is that reporting of multiple causes of death should provide a better description of a particular disease or condition, allowing for more effective and meaningful data capture. The reliability of statistical information extracted from death certificates however still remains uncertain, where for example, rather than the underlying chronic condition being reported, a secondary cause of death is often reported as the main cause of death. [6-14]

Increasing elderly population demographic changes worldwide along with exponential rises in chronic conditions, will most likely place greater social and fiscal demands on existing clinical health and social services. [15] To ensure that mortality and survival rates are more precisely captured for these chronic conditions, the relative contributions different diseases have upon survival and mortality need to be more accurately measured. The challenge is to ensure that more reliable data is recorded to allow for more efficient planning for healthcare services and clinical interventions. Parkinson's disease (PD) is a progressive neurodegenerative disease strongly associated with increased mortality and lower life expectancy than the general population. [16-28] In addition to the motor symptoms of PD, many patients often live with a significant number of other non-motor conditions which contribute to the symptomatology of the disease. [29-34] In particular, dementia occurs frequently in the elderly PD patient and has been shown to be a strong predictor for increased mortality. [25,35-45] This most probably has implications for the quality of death certification, which in previous investigations has been found to be inconsistent, under recorded or an inaccurate record of the cause of death in patients. [26,27,46-49] The methodological design of previous investigations, where cohorts have been drawn from clinical populations or pharmaceutical trails alone may partially explain the variability between studies.[50-52] Only a small number of investigations have employed prospective community study methods to ascertain the utility of death certification in PD, and furthermore few have included a comparison control group.

The aim of the present investigation is to examine the reported cause of death in a community cohort of PD patients and comparable group of individual's in the general population without neurological disease from the same geographical area. This will allow for exploration of the quality of death certification in these

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3 individuals and to determine how often PD and or dementia is
4 reported as a contributor to death in these individuals.

5 6 **Methods**

7 8 **Patient and Control subjects**

9
10 The PD Denbighshire cohort study provided data for analysis in the
11 current investigation. [25,37,53] This cohort and the control cohort
12 were drawn from a geographically defined area in North Wales
13 United Kingdom (UK), and followed from 1997-2015. At study entry
14 166 patients all of whom met clinical criteria for probable PD were
15 reviewed. [54] The causes of death were compared with a control
16 cohort (n = 102) recruited from General Practitioner practices within
17 the same geographical area from which the PD group was drawn.
18 The control cohort were initially screened for possible signs of
19 parkinsonism, Alzheimer's disease, history of a previous stroke,
20 any other neurological or neurocognitive disorder, if they were
21 found to have been treated with any psychoactive drugs, or a
22 significant psychiatric, alcohol or substance abuse history. The
23 included control subjects were matched for sex and of similar age
24 to PD patients (± 3 years).

25
26 The PD cohort at study entry were assessed with the Hoehn and
27 Yahr staging (H&Y), the UPDRS motor subsection, the 15-item
28 Geriatric Depression Scale (GDS), the Cambridge Examination for
29 Mental Disorders of the Elderly (CAMDEX), section B (CAMCOG),
30 the Parkinson's disease Activities of Daily Living Scale (PADL) and
31 the EuroQol, health related quality of life (HRQoL) measure.[16,55-
32 59] Demographic variables were recorded which included age,
33 gender, educational attainment, social class, onset age of PD
34 diagnosis, and the duration of PD symptoms. The diagnosis of
35 dementia was based upon neuropsychological assessment,
36 patient, and carer/informant interviews, along with the application of
37 the Diagnostic and Statistical Manual of Mental disorders fourth
38 edition criteria. [60]

39 40 **Death certification collection and evaluation.**

41
42 Review of hospital and primary care records were employed to
43 ascertain the number of individuals who were deceased. All of the
44 death certificates in this investigation were obtained from the local
45 Births, Deaths, and Marriages central record office for the PD and
46 control cohorts. Primary and underlying cause of death, along with
47 the age of the subject and the age of death are recorded on all
48 certificates in the UK. In addition, all certificates completed by a
49 doctor within the UK and are coded using the ICD-10 system as
50 follows:

51 Ia: Disease or condition leading directly to death.

52 I(b): Other disease or condition, if any, leading to I(a).

53 I(c): Other disease or condition, if any, leading to I(b)

54 II: Other significant conditions that contributing to death but not
55 related to the disease or condition causing it.

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3 From the information recorded on the death certificates, we
4 grouped primary and underlying causes of death in to nine further
5 categories which were, PD, Sepsis, Dementia, Cerebrovascular,
6 Cardiac, Cancer, Pneumonia, Chronic lung disease, other
7 disorders.

8 **Statistics.**

9
10 The age- and sex-specific standardised mortality ratios (SMR) were
11 calculated for men and women by dividing the observed number of
12 deaths in each group by the expected number of deaths in each
13 group. The expected numbers of deaths were calculated using the
14 published UK age- and sex-specific Office of National Statistics
15 (ONS).

16
17 Descriptive statistics (mean, SD, median) were used for continuous
18 variables, whereas categorical variables were described as
19 percentages of subjects in each group. Student t-tests, the chi-
20 square test, and Univariate logrank statistics were employed to
21 examine between-group differences and between observed and
22 expected survival curves (all values two-tailed, $p < 0.05$). The
23 survival time of subjects was calculated from the date of baseline
24 examination. The Kaplan-Meier estimates were used to calculate
25 the observed survival curves. Cox proportional hazard analysis was
26 employed to investigate if one or more covariates were related to
27 mortality. Cox proportional hazards and Cox time-dependent
28 models were used for the multivariate analysis. All data were
29 analysed with the SPSS statistical package version 19. [61] The
30 relative risk (RR) and 95% confidence interval (CI) were calculated
31 using the Altman formula and MedCalc software. [62,63]
32
33

34 **Results**

35
36 From baseline to the study end date (30/12/2015), 158/166 (96%)
37 of the PD and 34/102 (33%) of the control cohorts were decedents.
38 In Table 1 the demographic and clinical outcomes of the PD and
39 control cohorts are shown. Figure 1 illustrates the Kaplan-Meier
40 survival curves for all cause mortality in the PD and control cohorts.
41 The SMR for the whole PD cohort compared to the England &
42 Wales 2013 population was 1.82 (95% CI: 1.55 – 2.13). Comparing
43 prevalent and incident cases survival revealed an SMR of 1.72
44 (95% CI: 1.36 – 2.17), which indicated a non significant ($p < 0.186$)
45 excess mortality between the groups (Figure 2). There were no
46 statistical differences found between the PD and control cohorts
47 age at death (PD cohort 80.7 (7.1), Control cohort 81.9(6.3); $z =$
48 0.640; $p > 0.552$). The strongest predictor for mortality in the PD
49 cohort was the worsening motor symptoms (HR 1.06, $p < 0.01$).
50 As a primary cause of death (Part 1a on UK death certificates), PD
51 was recorded in just over 4% of the cohort. In sections 1b and 1c
52 (conditions substantially contributing to death), PD was reported in
53 24% and 6% of cases respectively. In section II of the death
54 certificates (co-morbid conditions substantially contributing to
55 death); PD was reported in 19% of cases. Overall, PD as a
56 contributing factor in the cause of death, was not reported
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anywhere on 75/158 (47%) of the cohort certificates. The primary cause of death for the PD and control cohorts is shown in figures 3 & 4. The most common cause of death reported within the PD cohort (figure 2) was pneumonia (52%), followed by cardiac related deaths (21%). The most frequently recorded cause of death within the control cohort (figure 3) was cardiac disease (26%), cancer (24%), and pneumonia (18%). A comparison between the PD and Control cohorts revealed that the PD cohort were nearly three times more likely to have pneumonia recorded as a primary cause of death (RR, 2.94, 95% CI 1.40-6.19). Controlling for patients and controls with dementia still revealed a higher risk of mortality in PD for pneumonia (RR, 2.03, 95% CI 1.34-3.6). The controls compared to the PD cohort had over a threefold increased risk of having a cancer related disorder recorded as a primary or underlying cause of death (RR, 3.72, 95% CI 1.58 -8.72).

Disease progression within the PD cohort was significantly associated with a worsening HRQoL at death ($z = 4.5$; $p < 0.0001$). When compared to the controls, HRQoL was significantly poorer for the PD cohort ($z = 3.29$; $p < 0.001$). At the time of death, 83/158 (52%) of the PD and 9/34 (26%) of the control cohorts were living in institutional care ($z = 2.96$, $p < 0.003$). Overall, the PD cohort decedents had a threefold increased probability to be living in institutional care at death (RR 3.23, 95% CI 1.4-7.41). Controlling for age and duration of illness, the PD cohort living in institutional care were also more likely to be demented (RR 2.7 (95% CI 1.21- 5.76). In contrast to the PD cohort, the control decedent's place of death was more likely to be in hospital (RR, 1.97, 1.48-2.62).

As a primary or underlying cause of death, dementia was underreported on both the PD and control certificates. Although 144/158 (91%) of the PD cohort had a diagnosis of dementia before their deaths, it was reported in only 14/144 of certificates. Similarly, only two of the control cohort had dementia recorded anywhere as a primary or underlying cause of death. Upon review however, a further four at the time of death had a confirmed diagnosis of dementia.

Discussion.

This investigation reports the cause of death recorded on the death certificates of PD and age matched control cohorts in Denbighshire in the UK. We have previously reported that the life expectancy and average age at death in this PD cohort is much lower than the general population. [25] In the current study the overall SMR for our PD cohort was 1.82, indicating an excess mortality, which remained even after controlling for prevalent cases of PD at baseline (SMR 1.72). This is similar to previous investigations where the SMR has been reported to range from 1.5 to 2.5. [22-26,28,49] However, recent community based incident cohort and incident clinical cohort investigations have reported lower SMR's of 1.29 (95% CI, 0.97-1.61), and 1.39 (95% CI, 1.10.-1.50), suggesting a moderate increase mortality compared to the general population. [28,64] The shorter duration of PD diagnosis, lower number of recorded deaths and shorter follow-up period compared with the current

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3 investigation may partially explain these differences the current and
4 previously reported UK investigation. In addition the Spanish
5 investigation was limited by the retrospective analysis of a data set
6 from 1978-1998 and recruitment solely from a clinical population.
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8 Overall death certification and clinical research data appear to
9 provide quite disparate mortality data in PD. Although our PD
10 cohort had confirmed UKPDSBB criteria for probable PD, as a
11 primary cause of death (Part 1a), it was recorded in just in over 4%
12 of the cohort. A further 30% had PD recorded in parts 1b and c of
13 their death certificates, and on Part II of certificates it was recorded
14 in a further 19% of cases. Overall, PD was not cited anywhere on
15 47% of the death certificates, which falls approximately midway
16 with previous certification studies of between 14–70%.
17 [22,26,27,46-49] The disparity reported between studies is most
18 likely evidence of the differing methodologies employed such as,
19 populations drawn from pharmaceutical trials alone, clinical
20 samples, or retrospective case or chart record analysis.
21

22 Pneumonia was the most cited primary cause of death (52%), with
23 near a threefold higher increased risk compared to the controls,
24 which has been frequently reported in other investigations. [22,26-
25 30,38,64] Patients with PD, particularly as they become frailer with
26 the progression of their illness, are at greater risk for pulmonary
27 complications, due to obstructive ventilation dysfunction, upper
28 airway dysfunction, and weakened strength of respiratory muscles.
29 [65-68] The most frequently reported other causes of death were
30 cardiovascular disease (21%), cerebrovascular disease (8%) and
31 malignancy (6%).
32

33 This is the first study to our knowledge to describe underreporting
34 of dementia as a primary, or underlying cause of death in a
35 community based PD cohort. We have previously reported in this
36 cohort the high prevalence of dementia of around 90%. [69] Upon
37 review of the decedents death certificates, we found that less than
38 10% had any mention of dementia as an immediate or underlying
39 cause of death. Previous general population investigations have
40 also shown that rates of certification mentioning dementia as a
41 main or underlying cause of death have been consistently under
42 reported. [70-73] This perhaps is because certification tends to
43 focus upon the immediate cause of death and does not really
44 capture the multiple factors that contribute to death, particularly
45 with elderly individuals with multiple co-morbidities.
46

47 This investigation found that the progression of PD motor severity,
48 poorer HRQoL and dementia increased the likelihood of entering
49 and residing in long term care before death. This may be a
50 reflection of the duration, nature and the type of burden PD places
51 upon relatives, especially those who have physical frailty
52 themselves. Caring within the home setting may therefore become
53 more impracticable and thus possibly precipitates entry into
54 institutional care. The proportion of deaths in long term care
55 amongst the PD cohort was also significantly higher than the
56 control cohort. In contrast, the number of hospital deaths in the PD
57 cohort was significantly lower than the control cohort (37% vs.
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3 73%) and more patients died at home (other than a long care
4 setting) compared to the controls (16% vs.12%). A recent study
5 reported wide variations in the place of death of people with PD
6 throughout the world, concluding that individual preference, social
7 and socioeconomic circumstances; cultural, organisation and
8 provision of health and palliative care all contribute to some extent
9 the place of death. [74]

10
11 In common with previous mortality investigations we found fewer
12 recorded cancer deaths within the PD cohort. [75] It is thought that
13 mutations of the PARK2 (Parkin) gene found in 6-8% of PD
14 patients may act in some cancers as a tumour suppressor proteins.
15 [76] The absence or mutation of the Parkin gene is found in several
16 tumour types, suggesting that the mechanisms of cell death in PD
17 may play a role in the inhibition or formation of some cancers. [77]
18 The decreased risk of mortality from cancer has also been reported
19 in other neurodegenerative disease including Alzheimer's,
20 Huntington's disease and in populations where mild to moderate
21 with cognitive impairment has also been observed. [78-81 Further
22 studies are needed to explore the associations, risks, possible
23 genetic markers and underlying mechanisms in PD and other
24 neurodegenerative conditions, to improve and identify and
25 understand the role of cell death and its decreased cancer risk.

26
27 We would caution the message often given to PD patients that they
28 die with, rather than die of the condition. The non-motor features of
29 PD such as dementia and autonomic dysfunction are frequently
30 observed in all stages of the disease and most likely make a
31 significant contribution to mortality.[82] A recent investigation
32 reported that autonomic dysfunction and dementia in PD was
33 predictive of increased mortality particularly in patients with
34 orthostatic hypotension (OH).[83] Another meta-analysis which
35 explored the association with OH and mortality in general
36 populations also concluded that OH may confer a greater risk (RR,
37 1.40) for mortality. [84] The association between the non-motor
38 features of PD disease and mortality needs further research to
39 understand and determine if these are causal or not.

40
41 This study's strengths are the robust follow-up over an 18-year
42 period of a community based cohort all of whom fulfilled criteria for
43 PD and diagnostic re-evaluation was reviewed regularly over this
44 period to ensure diagnostic accuracy. The repeat measure design
45 of the study also allowed us to control for demographics, and motor
46 and non-motor symptomatology. The limitations of the study are
47 that the PD cohort had a mix of prevalent and incident cases, thus
48 possibly over estimating the possible causal associations with
49 mortality. However, controlling for prevalent and incident cases in
50 our analysis did not reveal any between group significant
51 differences. In light of our findings we feel that the current methods
52 of capturing the cause of death significantly underestimate the true
53 population burden of PD. The under reporting of dementia as an
54 underlying cause of death in this cohort in addition to PD, also
55 suggests that the interpretation of and quality of mortality data
56 currently is not a valid or reliable source of data. Furthermore we
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3 would admonish the use of mortality statistics alone to plan for
4 future service provision in this patient population.
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8 **Contributorship statement:** PH and RJM conceived and designed
9 the study, collected the data, and managed the database. PH
10 managed the database, contributed to data cleaning, performed the
11 statistical analyses. PH and RJM contributed to interpretation of the
12 data. PH and RJM wrote the manuscript. All authors critically
13 reviewed the manuscript and approved the final version to be
14 published.
15

16 **Competing interests:** None declared.
17

18 **Funding:** This research received no specific grant from any funding
19 agency in the public, commercial or not-for-profit sectors.
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21 **Data sharing statement:** No additional data available.
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For peer review only

Table 1:
Demographic and clinical outcomes of the PD and control cohorts

	Parkinson's disease	Control	<i>p</i> < 0.05
Gender (female %)	44%	41%	NS
Age at death	80.7 (7.1)	81.9 (6.3)	NS
Institutional care %	52%	30%	0.003
Place of death (Hospital)	37%	74%	0.002
EQ-5D (Weighted health)	0.58 (0.36)	0.79 (0.28)	0.001
EQ-5D (VAS %)	55 (16.5)	77 (17.6)	0.001
Onset of PD	67.3(10.7)	-----	-----
Duration of PD	13.2 (8.8)	-----	-----
UPDRS (motor section)	27.9(11.7)	-----	-----
H & Y	2.9 (0.74)	-----	-----
PADL	3.1 (1.1)	-----	-----

Figure 1.
Kaplan-Meier survival curves for all cause mortality in the PD and control cohorts

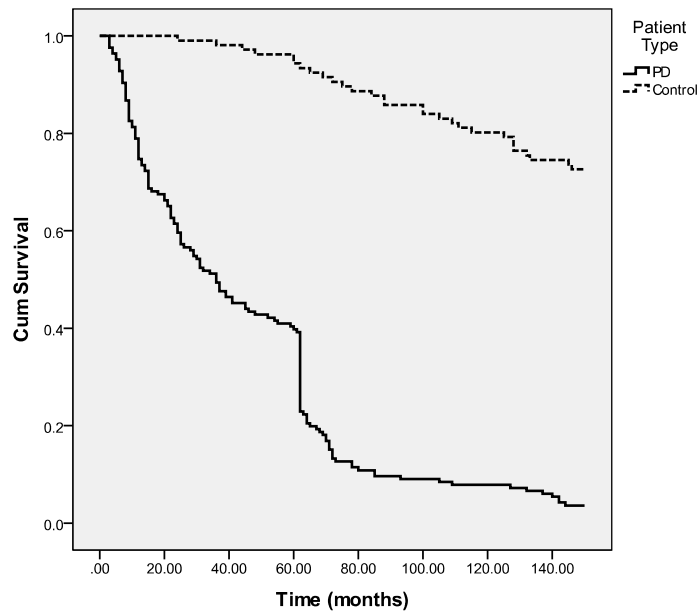


Figure 2: Survival curve analysis comparison between prevalent (n=76) and incident (n=80) PD cases.

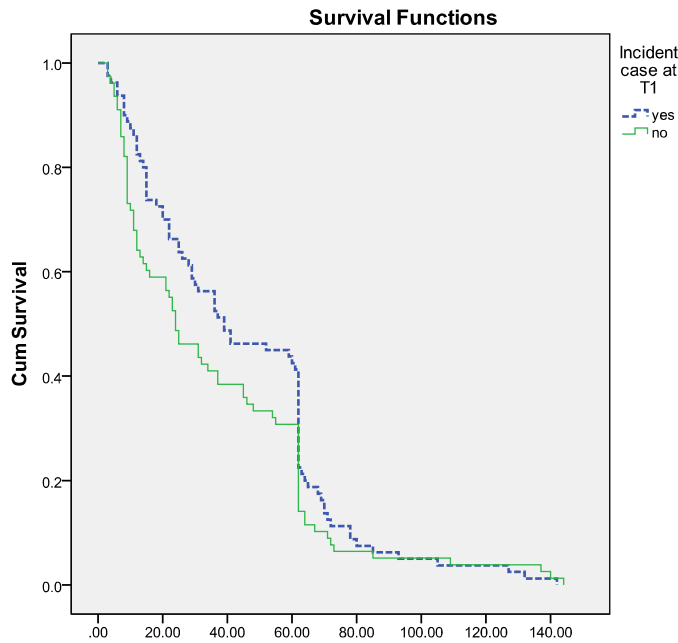


Figure 3: Primary cause of death reported for the PD cohort.

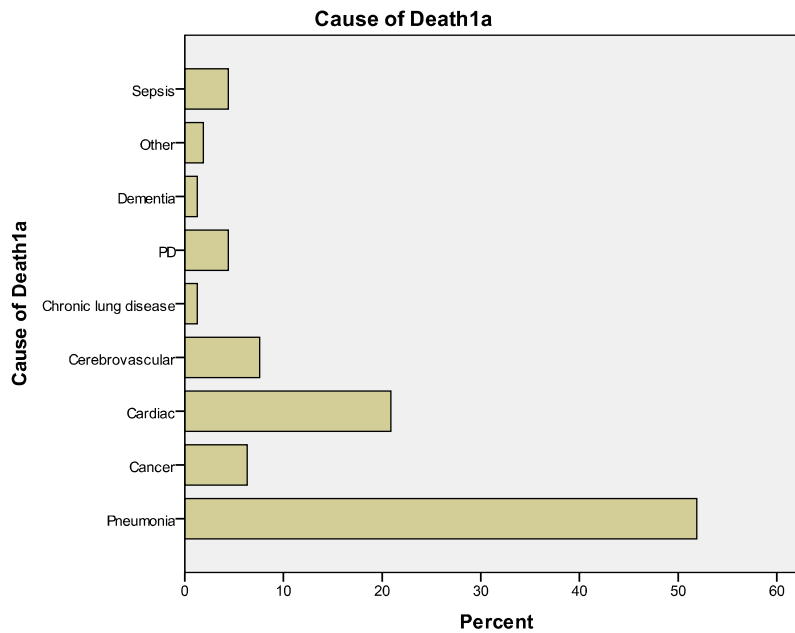
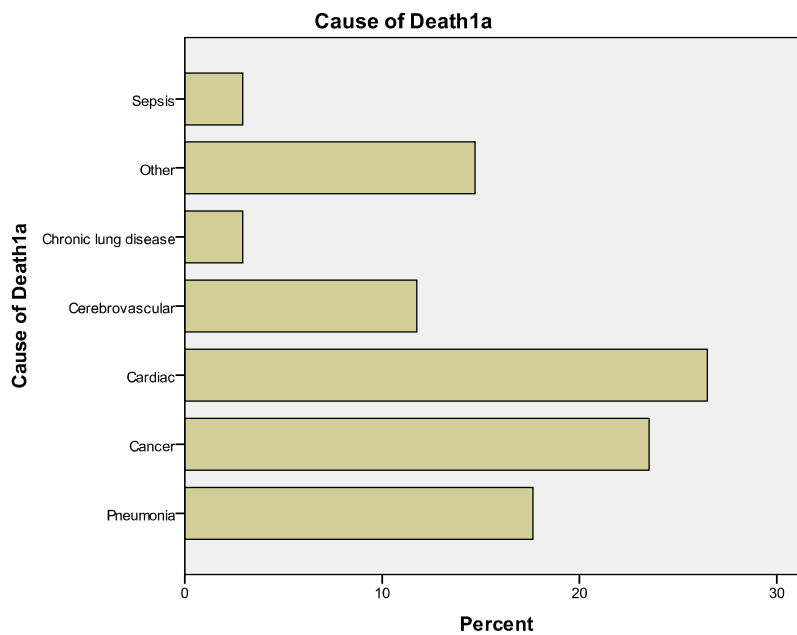


Figure 4: Primary cause of death reported for the control cohort.



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STROBE 2007 (v4) checklist of items to be included in reports of observational studies in epidemiology*
Checklist for cohort, case-control, and cross-sectional studies (combined)

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(a) Indicate the study’s design with a commonly used term in the title or the abstract	1
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3
Objectives	3	State specific objectives, including any pre-specified hypotheses	3,4
Methods			
Study design	4	Present key elements of study design early in the paper	4
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	4
Participants	6	(a) <i>Cohort study</i> —Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up <i>Case-control study</i> —Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls <i>Cross-sectional study</i> —Give the eligibility criteria, and the sources and methods of selection of participants	4
		(b) <i>Cohort study</i> —For matched studies, give matching criteria and number of exposed and unexposed <i>Case-control study</i> —For matched studies, give matching criteria and the number of controls per case	4
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	4
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	4,5
Bias	9	Describe any efforts to address potential sources of bias	5,6,8
Study size	10	Explain how the study size was arrived at	n/a
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	n/a
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	5
		(b) Describe any methods used to examine subgroups and interactions	5
		(c) Explain how missing data were addressed	n/a
		(d) <i>Cohort study</i> —If applicable, explain how loss to follow-up was addressed <i>Case-control study</i> —If applicable, explain how matching of cases and controls was addressed	n/a

		<i>Cross-sectional study</i> —If applicable, describe analytical methods taking account of sampling strategy	
		(e) Describe any sensitivity analyses	n/a
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	5
		(b) Give reasons for non-participation at each stage	n/a
		(c) Consider use of a flow diagram	--
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	5
		(b) Indicate number of participants with missing data for each variable of interest	n/a
		(c) <i>Cohort study</i> —Summarise follow-up time (eg, average and total amount)	5,6
Outcome data	15*	<i>Cohort study</i> —Report numbers of outcome events or summary measures over time	5,6
		<i>Case-control study</i> —Report numbers in each exposure category, or summary measures of exposure	5,6
		<i>Cross-sectional study</i> —Report numbers of outcome events or summary measures	--
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	5,6
		(b) Report category boundaries when continuous variables were categorized	5,6
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	5,6
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	5,6
Discussion			
Key results	18	Summarise key results with reference to study objectives	6
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	8
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	8
Generalisability	21	Discuss the generalisability (external validity) of the study results	6-8
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	9

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at www.strobe-statement.org.

BMJ Open

Mortality and the quality of death certification in cohort of Parkinson's disease and matched controls in North Wales United Kingdom at 18-years: a community based cohort study.

Journal:	<i>BMJ Open</i>
Manuscript ID	bmjopen-2017-018969.R1
Article Type:	Research
Date Submitted by the Author:	23-Sep-2017
Complete List of Authors:	Hobson, Peter; Academic Unit Meara, Jolyon; Academic Unit
Primary Subject Heading:	Neurology
Secondary Subject Heading:	Epidemiology
Keywords:	Parkinson-s disease < NEUROLOGY, Mortality, Death certification, Dementia < NEUROLOGY

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3 Mortality and the quality of death certification in cohort of
4 Parkinson's disease and matched controls in North Wales United
5 Kingdom at 18-years: a community based cohort study.
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26 Keywords:
27 Parkinson's disease, Mortality, Death certification, Dementia
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29 Word count: 3213
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Abstract

Objective: To estimate the survival, mortality and quality of death certification in a community cohort of Parkinson's disease (PD) patients and controls in North Wales United Kingdom (UK).

Setting and participants: A total of 166 PD patients and 102 controls were included in this investigation. Hospital and primary care records were employed to ascertain the number of individuals who died during the investigation period. The primary and underlying cause of death was extracted from certificates obtained from the UK General Register Office.

Results: There were 158 (95%) deaths in the PD and 34 (33%) deaths recorded in the control cohort. The Standard Mortality Rate (SMR) was 1.82 (95% CI: 1.55 – 2.13). The main cause of death reported in the PD cohort was pneumonia (53%), followed by cardiac related deaths (21%). PD as the primary or underlying cause was not reported in 75/158 (47%) of the cohort. In addition, although 144 of the cohort had a diagnosis of dementia, this was reported in less than 10% (n=14) of their death certificates.

Conclusion: This community based investigation established that PD is associated with a higher risk of mortality compared to the general population. In addition, we found that the majority of patients with PD if they survive long enough will develop dementia. However, the reporting of PD and dementia as a cause or underlying cause of death on certificates was found to be suboptimal. The results from this investigation suggest that use of mortality statistics derived from death certification alone in epidemiological studies, healthcare planning and provision need to be reconsidered, because they are not a valid or reliable source of data capture.

Strengths and limitations

- Community based longitudinal follow-up cohort design.
- All patients fulfilled diagnostic criteria for Parkinson's disease and or dementia.
- Baseline and subsequent repeat measure data capture allowed analysis for predictive outcomes.
- The cohort included prevalent and new cases Parkinson's disease. Although the varying disease duration of the Parkinson's disease cohort is a possible source of bias, we found no differences between the two groups survival.
- The control cohort included subjects without known neurological condition and thus may have intruded bias in the outcome comparisons with the Parkinson's disease patients.

Introduction

Data drawn from death certificates is often employed by epidemiological, public health and research scientists to capture the incidence, prevalence and mortality in populations. In addition, these statistics are often utilized in the evaluation of public health interventions, setting priorities for medical research and health services, the planning of health services, and the clinical assessment of the effectiveness of those services. [1-3] The introduction of the revised International Classification of Diseases (ICD) system in 2001 aim was to improve the accuracy in the reported cause of death, where underlying conditions, mentioned in Part 1 or 2 of death certification take priority over others. [4,5] The underlying principle for this is that reporting of multiple causes of death should provide a better description of a particular disease or condition, allowing for more effective and meaningful data capture. The reliability of statistical information extracted from death certificates however still remains uncertain, where for example, rather than the underlying chronic condition being reported, a secondary cause of death is often reported as the main cause of death. [6-14]

Increasing elderly population demographic changes worldwide along with exponential rises in chronic conditions, will most likely place greater social and fiscal demands on existing clinical health and social services. [15] To ensure that mortality and survival rates are more precisely captured for these chronic conditions, the relative contributions different diseases have upon survival and mortality need to be more accurately measured. The challenge is to ensure that more reliable data are recorded to allow for more efficient planning for healthcare services and clinical interventions. Parkinson's disease (PD) is a progressive neurodegenerative disease strongly associated with increased mortality and lower life expectancy than the general population. [16] In addition to the motor symptoms of PD, many patients often live with a significant number of other non-motor conditions which contribute to the symptomatology of the disease. [17-22] In particular, dementia occurs frequently in the elderly PD patient and has been shown to be a strong predictor for increased mortality. [23-33] This most probably has implications for the quality of death certification, which in previous investigations has been found to be inconsistent, under recorded or an inaccurate record of the cause of death in patients. [16,34-37] The methodological design of previous investigations, where cohorts have been drawn from clinical populations or pharmaceutical trails alone may partially explain the variability between studies.[39-40] Only a small number of investigations have employed prospective community study methods to ascertain the utility of death certification in PD, and furthermore few have included a comparison control group.

This investigation is a report of the outcomes from a community cohort of PD patient and controls (without neurological disease) who have been regularly followed over the past 18 years in the county of Denbighshire in the United Kingdom. It aims firstly to examine the reported cause and quality of death certification in

1
2
3 these cohorts. Secondly, it will explore if PD and or dementia are
4 reported as a cause or underlying cause of death on certificates.
5 Thirdly, the demographic, motor and non-motor symptoms of PD
6 will be explored to establish if they are associated or predictive with
7 an increased risk of mortality.

8 **Methods**

9 **Subjects**

10
11
12 The patient and control recruitment methodology has been
13 described in greater depth in previous reports [25,41]. In brief,
14 between December 1994 and January 1997, employing multiple
15 sources of ascertainment we recruited newly diagnosed PD
16 patients and patients with an existing diagnosis of probable PD
17 based upon the UKPDS brain bank criteria. [42] General
18 practitioner (GP) records (n=74) in a defined Area of North Wales
19 (Denbighshire), were employed to identify individuals in receipt of a
20 defined group of anti-parkinsonian drugs, which included
21 Levodopa, monomine-oxidase-B inhibitors, dopamine agonists and
22 anti-muscarinic drugs. Additionally, hospital records were examined
23 and patients who were not on active but known to medical services
24 were also ascertained. In total, 402 patients were identified, of
25 whom 213 fulfilled criteria for clinically probable PD patients (n=
26 213). Of the original PD cohort, 25 died before they could be
27 consented into the investigation, 13 withdrew consent and the
28 remaining patients (n = 9) were lost to follow-up. This left at study
29 entry 166 probable PD patients for follow-up from December 1997
30 to January 2015.

31
32
33 The control cohort was randomly drawn from two GP practices
34 within the same geographical area of the PD cohort within the
35 same time frame. The controls were matched for sex and age to
36 PD patients (\pm 3 years), were not known to have a diagnosis of
37 clinically probable PD, parkinsonism, Alzheimer's or other
38 dementia, stroke, neurological disorder, not in receipt of
39 psychoactive drugs and did not have a known psychiatric, alcohol
40 or substance abuse history. A total of 164 controls were invited to
41 participate in the study, of whom 42 subsequently declined to
42 participate and a further six withdrew consent at a later date. Upon
43 initial baseline screening, eight were found to have previously
44 suffered from a stroke, two had signs of parkinsonism and four
45 fulfilled criteria for dementia and were excluded from further
46 analysis, leaving a cohort of 102 control subjects.

47 **Clinical assessment.**

48
49 The PD cohort demographic variables were recorded which
50 included age, gender, educational attainment, social class, age of
51 PD diagnosis, and the duration of PD symptoms at study entry.
52 They were also assessed with the Hoehn and Yahr staging (H&Y),
53 the UPDRS motor subsection, the 15-item Geriatric Depression
54 Scale (GDS -15), the Cambridge Examination for Mental Disorders
55 of the Elderly (CAMDEX), section B (CAMCOG), the Parkinson's
56 disease Activities of Daily Living Scale (PADL) and the health
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3 related quality of life (HRQoL) measure the EQ5-D.[43-47] These
4 measures were reassessed at approximately two yearly intervals
5 from the midpoint of the recruitment phase of the cohort assembly.
6 Diagnosis of PD based upon UKPDBB criteria was reassessed
7 (RJM) at review to ensure diagnostic accuracy was maintained.
8 The control cohort screening was also carried out approximately
9 every two years from study entry which included review and
10 updating of demographic variables, and reassessment with the
11 GDS-15, CAMCOG, and EQ5-D. Analysis of the clinical
12 assessments was the most recent prior to a subjects reported
13 death. The diagnosis of dementia for PD and controls was based
14 upon neuropsychological assessment, patient, and carer/informant
15 interviews, along with the application of the Diagnostic and
16 Statistical Manual of Mental disorders fourth edition criteria. [48]
17

18 **Death certification collection and evaluation.**

19
20 Review of hospital and primary care records were employed to
21 ascertain the number of individuals who were deceased. All of the
22 death certificates in this investigation were obtained from the local
23 Births, Deaths, and Marriages central record office for the PD and
24 control cohorts. Primary and underlying cause of death, along with
25 the age of the subject and the age of death are recorded on all
26 certificates in the UK. In addition, all certificates completed by a
27 doctor within the UK and are coded using the ICD-10 system as
28 follows:

29 Ia: Disease or condition leading directly to death.
30 I(b): Other disease or condition, if any, leading to I(a).
31 I(c): Other disease or condition, if any, leading to I(b)
32 II: Other significant conditions that contributing to death but not
33 related to the disease or condition causing it.
34

35 From the information recorded on the death certificates, we
36 grouped primary and underlying causes of death in to nine further
37 categories which were, PD, Sepsis, Dementia, Cerebrovascular,
38 Cardiac, Cancer, Pneumonia, Chronic lung disease, other
39 disorders.
40

41 **Ethical approval:**

42 **This study was approved by the North Wales Research and**
43 **ethics committee (Central).**
44

45 **Statistics.**

46
47 The standardized mortality (SMR) was calculated as the ratio of
48 observed deaths in the study group to expected deaths by
49 employing age and gender specific morality rates for each year of
50 the investigation, drawn from the UK Office of National Statistics
51 interim life tables.
52

53 Descriptive statistics (mean, SD, median) were used for continuous
54 variables, whereas categorical variables were described as
55 percentages of subjects in each group. Student t-tests, the chi-
56 square test, and Univariate logrank statistics were employed to
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3 examine between-group differences and between observed and
4 expected survival curves (all values two-tailed, $p < 0.05$). The
5 survival time of subjects was calculated from the date of baseline
6 examination. The Kaplan-Meier estimates were used to calculate
7 the observed survival curves. Cox proportional hazard analysis was
8 employed to investigate baseline demographic and clinical
9 covariates were related to mortality. Covariates included in the
10 models, age at study entry, Age at death, gender, motor function
11 (PD cohort), mood, HRQoL, and cognitive function. All data were
12 analysed with the SPSS statistical package version 19. [49] The
13 relative risk (RR) and 95% confidence interval (CI) were calculated
14 using the Altman formula and MedCalc software. [50,51]
15

16 17 **Results**

18
19 From baseline to the study end date (30/01/2015), 158/166 (96%)
20 of the PD and 34/102 (33%) of the control cohorts were decedents.
21 In Table 1 the demographic and clinical outcomes of the PD and
22 control cohorts are shown. Figure 1 illustrates the Kaplan-Meier
23 survival curves for all cause mortality in the PD and control cohorts.
24 The SMR for the whole PD cohort was 1.82 (95% CI: 1.55 – 2.13).
25 A sub group analysis between new cases of PD ($n = 80$) identified
26 during the cases ascertainment phase of the investigation and
27 existing cases of PD ($n = 78$) revealed no excess mortality between
28 the groups ($p = 0.186$) despite the varying disease duration. By 18
29 years the cumulative survival in the PD cohort (figure 1), was
30 approximately 5% and 67% in the control cohort. The mortality risk
31 controlled for age and gender was significantly higher risk in the PD
32 cohort (HR 7.89, $p = 0.0001$). Older age at entry into the current
33 study was predictive of an increased risk of mortality in both cohorts
34 (PD: HR 1.06, $p = 0.0001$; Control: HR 1.09, $p = 0.009$). There
35 were no statistical differences found between the PD and control
36 cohorts age at death (PD cohort 80.7 (7.1), Control cohort
37 81.9(6.3); $p = 0.552$). The strongest predictor associated with
38 mortality in the PD cohort after controlling for age and gender was
39 worsening motor symptoms (HR 1.06, $p < 0.01$).
40

41 As a primary cause of death (Part 1a on UK death certificates), PD
42 was recorded in just over 4% of the cohort. In sections 1b and 1c
43 (conditions substantially contributing to death), PD was reported in
44 24% and 6% of cases respectively. In section II of the death
45 certificates (co-morbid conditions substantially contributing to
46 death); PD was reported in 19% of cases. Overall, PD as a
47 contributing factor in the cause of death, was not reported
48 anywhere on 75/158 (47%) of the PD cohort's certificates. The
49 primary cause of death for the PD and control cohorts is shown in
50 figures 2 & 3. The most common causes of death reported within
51 the PD cohort (figure 2) were pneumonia (53%), followed by
52 cardiac related deaths (21%). The most frequently recorded cause
53 of death within the control cohort (figure 3) was cardiac disease
54 (26%), cancer (24%), and pneumonia (18%). A comparison
55 between the PD and Control cohorts revealed that the PD cohort
56 were nearly three times more likely to have pneumonia recorded as
57 a primary cause of death (RR, 2.94, 95% CI 1.40-6.19), Controlling
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3 for patients and controls with dementia still revealed a higher risk of
4 mortality in PD for pneumonia (RR, 2.03, 95% CI 1.34-3.6). The
5 controls compared to the PD cohort had over a threefold increased
6 risk of having a cancer related disorder recorded as a primary or
7 underlying cause of death (RR, 3.72, 95% CI 1.58 -8.72).

8
9 Disease progression within the PD cohort was significantly
10 associated with a worsening HRQoL at death ($p < 0.0001$). When
11 compared to the controls, HRQoL was significantly poorer for the
12 PD cohort ($p < 0.001$). At the time of death, 83/158 (52%) of the PD
13 and 9/34 (26%) of the control cohorts were living in institutional
14 care ($p < 0.003$). Overall, the PD cohort decedents had a threefold
15 increased probability to be living in institutional care at death (RR
16 3.23, 95% CI 1.4-7.41). Controlling for age and duration of illness,
17 the PD cohort living in institutional were also more likely to be
18 demented (RR 2.7 (95% CI 1.21- 5.76). In contrast to the PD
19 cohort, the control decedent's place of death was more likely to be
20 in hospital (RR, 1.97, 1.48-2.62).

21
22 As a primary or underlying cause of death, dementia was
23 underreported on both the PD and control certificates. Although
24 144/158 (91%) of the PD cohort had a diagnosis of dementia
25 before their deaths, it was reported in only 14/144 of certificates.
26 Similarly, only two of the control cohort had dementia recorded
27 anywhere as a primary or underlying cause of death. Upon review
28 however, a further four at the time of death had a confirmed
29 diagnosis of dementia.

30 31 **Discussion.**

32
33 This investigation reports the cause of death recorded on the death
34 certificates of PD and age matched control cohorts in Denbighshire
35 in the UK. We have previously reported that the life expectancy and
36 average age at death in this PD cohort is much lower than the
37 general population. [16] In the current study the overall SMR for our
38 PD cohort was 1.82, indicating an excess mortality. This is similar
39 to previous investigations where the SMR has been reported to
40 range from 0.9 to 3.8 [16] However, recent community based
41 incident cohort and incident clinical cohort investigations have
42 reported lower SMR's of 1.29 (95% CI, 0.97-1.61), and 1.39 (95%
43 CI, 1.10.-1.50), suggesting a moderate increase mortality
44 compared to the general population. [16,52] The shorter duration of
45 PD diagnosis, lower number of recorded deaths and shorter follow-
46 up period compared with the current investigation may partially
47 explain these differences the current and previously reported UK
48 investigation. In addition the other European investigation was
49 limited by the retrospective analysis of a data set from 1978-1998
50 and recruitment solely from a clinical population.

51
52 Overall death certification and clinical research data appear to
53 provide quite disparate mortality data in PD. Although our PD
54 cohort had confirmed UKPDSBB criteria for probable PD, as a
55 primary cause of death (Part 1a), it was recorded in just in over 4%
56 of the cohort. A further 30% had PD recorded in parts 1b and c of
57 their death certificates, and on Part II of certificates it was recorded

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3 in a further 19% of cases. Overall, PD was not cited anywhere on
4 47% of the death certificates, which falls approximately midway
5 with previous certification studies of between 14–70%. [16,34-37]
6 The disparity reported between studies is most likely evidence of
7 the differing methodologies employed such as, populations drawn
8 from pharmaceutical trials alone, clinical samples, or retrospective
9 case or chart record analysis.

10
11 Pneumonia was the most cited primary cause of death (52%), in
12 the current study. This observation has also been frequently
13 reported in other investigations. [16,52] Patients with PD,
14 particularly as they become frailer with the progression of their
15 illness, are at greater risk for pulmonary complications, due to
16 obstructive ventilation dysfunction, upper airway dysfunction, and
17 weakened strength of respiratory muscles. [53-55] The most
18 frequently reported other causes of death were cardiovascular
19 disease (21%), cerebrovascular disease (8%) and malignancy
20 (6%).

21
22 This is the first study to our knowledge to describe underreporting
23 of dementia as a primary, or underlying cause of death in a
24 community based PD cohort. We have previously reported in this
25 cohort the high prevalence of dementia of around 90%. [56] Upon
26 review of the decedents death certificates, we found that less than
27 10% had any mention of dementia as an immediate or underlying
28 cause of death. Previous general population investigations have
29 also shown that rates of certification mentioning dementia as a
30 main or underlying cause of death have been consistently under
31 reported. [57-60] This perhaps is because certification tends to
32 focus upon the immediate cause of death and does not really
33 capture the multiple factors that contribute to death, particularly
34 with elderly individuals with multiple co-morbidity.

35
36 This investigation found that the PD cohort were more likely than
37 the controls to be living in a long term care setting before death.
38 This may be a reflection of the duration, nature and the type of
39 burden PD places upon relatives, especially those who have
40 physical frailty themselves. Caring within the home setting may
41 therefore become more impracticable and thus possibly
42 precipitates entry into institutional care. The proportion of deaths in
43 long term care amongst the PD cohort was also significantly higher
44 than the control cohort. A recent study reported wide variations in
45 the place of death of people with PD throughout the world,
46 concluding that individual preference, social and socioeconomic
47 circumstances; cultural, organisation and provision of health and
48 palliative care all contribute to some extent the place of death. [61]

49
50 In common with previous mortality investigations we found fewer
51 recorded cancer deaths within the PD cohort. [62] It is thought that
52 mutations of the PARK2 (Parkin) gene found in 6-8% of PD
53 patients may act in some cancers as a tumour suppressor proteins.
54 [63] The absence or mutation of the Parkin gene is found in several
55 tumour types, suggesting that the mechanisms of cell death in PD
56 may play a role in the inhibition or formation of some cancers.
57 [64,65] The decreased risk of mortality from cancer has also been

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3 reported in other neurodegenerative disease including Alzheimer's,
4 Huntington's disease and in populations where mild to moderate
5 with cognitive impairment has also been observed. [66-69] Further
6 studies are needed to explore the associations, risks, possible
7 genetic markers and underlying mechanisms in PD and other
8 neurodegenerative conditions, to improve and identify and
9 understand the role of cell death and its decreased cancer risk.

10
11 We would caution the message often given to PD patients that they
12 die with, rather than die of the condition. The non-motor features of
13 PD such as dementia and autonomic dysfunction are frequently
14 observed in all stages of the disease and most likely make a
15 significant contribution to mortality.[70] One recent investigation
16 reported that autonomic dysfunction and dementia in PD was
17 predictive of increased mortality particularly in patients with
18 orthostatic hypotension (OH).[71] Another meta-analysis which
19 explored the association with OH and mortality in general
20 populations also concluded that OH may confer a greater risk (RR,
21 1.40) for mortality. [72] The association between the non-motor
22 features of PD disease and mortality needs further research to
23 understand and determine if these are causal or not.

24
25 This study's strengths are the robust follow-up over an 18-year
26 period of a community based cohort all of whom fulfilled criteria for
27 PD and diagnostic re-evaluation was reviewed regularly over this
28 period to ensure diagnostic accuracy. The repeat measure design
29 of the study also allowed us to control for demographics, and motor
30 and non-motor symptomatology. The limitations of the study are
31 that the PD cohort had a mix of prevalent and incident cases, thus
32 possibly over estimating the possible causal associations with
33 mortality. However, controlling for prevalent and incident cases in
34 our analysis did not reveal any between group significant
35 differences. In light of our findings we feel that the current methods
36 of capturing the cause of death significantly underestimate the true
37 population burden of PD. The under reporting of dementia as an
38 underlying cause of death in this cohort in addition to PD, also
39 suggests that the interpretation of and quality of mortality data
40 currently is not a valid or reliable source of data. Furthermore we
41 would admonish the use of mortality statistics alone to plan for
42 future service provision in this patient population.

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Figure legends:

Figure 1.
Kaplan-Meier survival curves for all cause mortality in the PD and control cohorts.

Figure 2: Primary cause of death (Part 1a death certificates) reported for the PD cohort.

Figure 3: Primary cause of death (Part 1a death certificates) reported for the control cohort.

Table 1:
Demographic and clinical outcomes (Means, *standard deviations*) of the PD and control cohorts

	Parkinson's disease	Control	<i>p</i> < 0.05
Gender (female %)	44%	41%	NS
Age (entry into study)	74.2 (8.6)	74.8 (6.6)	NS
Age at death	80.7 (7.1)	81.9 (6.3)	NS
Institutional care %	52%	30%	0.003
Place of death (Hospital)	37%	74%	0.002
EQ-5D (Weighted health)	0.58 (0.36)	0.79 (0.28)	0.001
EQ-5D (VAS %) [†]	55 (16.5)	77 (17.6)	0.001
Onset of PD	67.3 (10.7)	-----	-----
Duration of PD	13.2 (8.8)	-----	-----
UPDRS (motor section)	27.9 (11.7)	-----	-----
H & Y	2.9 (0.74)	-----	-----
PADL	3.1 (1.1)	-----	-----

[†] VAS = EQ-%D Visual analogue scale

Funding: This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors.

Contributors: PH and RJM conceived and designed the study, collected the data, and managed the database. PH managed the database, contributed to data cleaning, performed the statistical analyses. PH and RJM contributed to interpretation of the data. PH and RJM wrote the manuscript. All authors critically reviewed the manuscript and approved the final version to be published.

Competing interests: None declared.

Patient consent: All participants gave their informed and written consent on participation.

Data sharing statement: No additional data available.

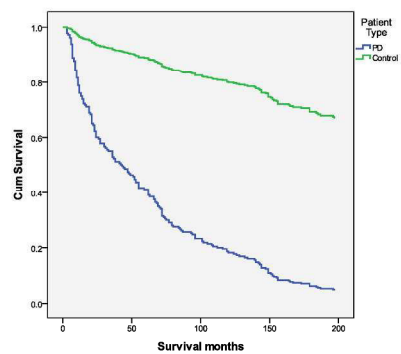


Figure 1.
Kaplan-Meier survival curves for all cause mortality in the PD and control cohorts.

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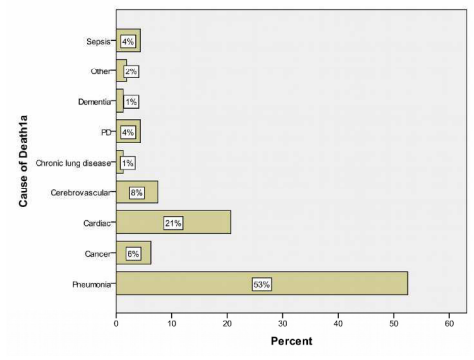


Figure 2: Primary cause of death (Part 1a death certificates) reported for the PD cohort.

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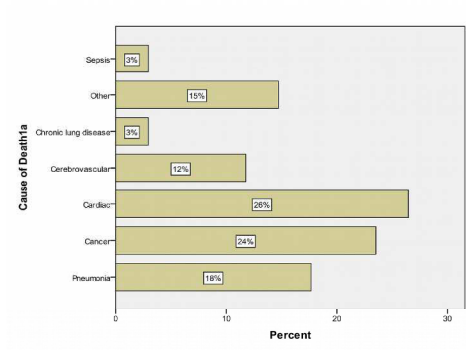


Figure 3: Primary cause of death (Part 1a death certificates) reported for the control cohort.

297x420mm (300 x 300 DPI)

STROBE 2007 (v4) checklist of items to be included in reports of observational studies in epidemiology*
Checklist for cohort, case-control, and cross-sectional studies (combined)

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(a) Indicate the study’s design with a commonly used term in the title or the abstract	1
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3
Objectives	3	State specific objectives, including any pre-specified hypotheses	3,4
Methods			
Study design	4	Present key elements of study design early in the paper	4
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	4
Participants	6	(a) <i>Cohort study</i> —Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up <i>Case-control study</i> —Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls <i>Cross-sectional study</i> —Give the eligibility criteria, and the sources and methods of selection of participants	4
		(b) <i>Cohort study</i> —For matched studies, give matching criteria and number of exposed and unexposed <i>Case-control study</i> —For matched studies, give matching criteria and the number of controls per case	4
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	4
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	4,5
Bias	9	Describe any efforts to address potential sources of bias	5,6,8
Study size	10	Explain how the study size was arrived at	n/a
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	n/a
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	5
		(b) Describe any methods used to examine subgroups and interactions	5
		(c) Explain how missing data were addressed	n/a
		(d) <i>Cohort study</i> —If applicable, explain how loss to follow-up was addressed <i>Case-control study</i> —If applicable, explain how matching of cases and controls was addressed	n/a

		<i>Cross-sectional study</i> —If applicable, describe analytical methods taking account of sampling strategy	
		(e) Describe any sensitivity analyses	n/a
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	5
		(b) Give reasons for non-participation at each stage	n/a
		(c) Consider use of a flow diagram	--
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	5
		(b) Indicate number of participants with missing data for each variable of interest	n/a
		(c) <i>Cohort study</i> —Summarise follow-up time (eg, average and total amount)	5,6
Outcome data	15*	<i>Cohort study</i> —Report numbers of outcome events or summary measures over time	5,6
		<i>Case-control study</i> —Report numbers in each exposure category, or summary measures of exposure	5,6
		<i>Cross-sectional study</i> —Report numbers of outcome events or summary measures	--
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	5,6
		(b) Report category boundaries when continuous variables were categorized	5,6
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	5,6
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	5,6
Discussion			
Key results	18	Summarise key results with reference to study objectives	6
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	8
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	8
Generalisability	21	Discuss the generalisability (external validity) of the study results	6-8
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	9

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at www.strobe-statement.org.

BMJ Open

Mortality and the quality of death certification in cohort of Parkinson's disease and matched controls in North Wales United Kingdom at 18-years: a community based cohort study.

Journal:	<i>BMJ Open</i>
Manuscript ID	bmjopen-2017-018969.R2
Article Type:	Research
Date Submitted by the Author:	13-Nov-2017
Complete List of Authors:	Hobson, Peter; Academic Unit Meara, Jolyon; Academic Unit
Primary Subject Heading:	Neurology
Secondary Subject Heading:	Epidemiology
Keywords:	Parkinson-s disease < NEUROLOGY, Mortality, Death certification, Dementia < NEUROLOGY

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Manuscripts

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3 Mortality and the quality of death certification in cohort of
4 Parkinson's disease and matched controls in North Wales United
5 Kingdom at 18-years: a community based cohort study.
6

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26 Keywords:
27 Parkinson's disease, Mortality, Death certification, Dementia
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29 Word count: 4030
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Abstract

Objective: To estimate the survival, mortality and quality of death certification in a community cohort of Parkinson's disease (PD) patients and controls in North Wales United Kingdom (UK).

Setting and participants: A total of 166 PD patients and 102 controls were included in this investigation. Hospital and primary care records were employed to ascertain the number of individuals who died during the investigation period. The primary and underlying cause of death was extracted from certificates obtained from the UK General Register Office.

Results: There were 158 (95%) deaths in the PD and 34 (33%) deaths recorded in the control cohort. The Standard Mortality Rate (SMR) was 1.82 (95% CI: 1.55 – 2.13). The main cause of death reported in the PD cohort was pneumonia (53%), followed by cardiac related deaths (21%). PD as the primary or underlying cause was not reported in 75/158 (47%) of the cohort. In addition, although 144 of the cohort had a diagnosis of dementia, this was reported in less than 10% (n=14) of their death certificates.

Conclusion: This community based investigation established that PD is associated with a higher risk of mortality compared to the general population. In addition, we found that the majority of patients with PD if they survive long enough will develop dementia. However, the reporting of PD and dementia as a cause or underlying cause of death on certificates was found to be suboptimal. The results from this investigation suggest that use of mortality statistics derived from death certification alone in epidemiological studies, healthcare planning and provision need to be reconsidered, because they are not a valid or reliable source of data capture.

Strengths and limitations

- Community based longitudinal follow-up cohort design.
- All patients fulfilled diagnostic criteria for Parkinson's disease and or dementia.
- Baseline and subsequent repeat measure data capture allowed analysis for predictive outcomes.
- The cohort included prevalent and new cases Parkinson's disease. Although the varying disease duration of the Parkinson's disease cohort is a possible source of bias, we found no differences between the two groups survival.
- The control cohort included subjects without known neurological condition and thus may have intruded bias in the outcome comparisons with the Parkinson's disease patients.

Introduction

Data drawn from death certificates is often employed by epidemiological, public health and research scientists to capture the incidence, prevalence and mortality in populations. In addition, these statistics are often utilized in the evaluation of public health interventions, setting priorities for medical research and health services, the planning of health services, and the clinical assessment of the effectiveness of those services. [1-3] The introduction of the revised International Classification of Diseases (ICD) system in 2001 aim was to improve the accuracy in the reported cause of death, where underlying conditions, mentioned in Part 1 or 2 of death certification take priority over others. [4,5] The underlying principle for this is that reporting of multiple causes of death should provide a better description of a particular disease or condition, allowing for more effective and meaningful data capture. The reliability of statistical information extracted from death certificates however still remains uncertain, where for example, rather than the underlying chronic condition being reported, a secondary cause of death is often reported as the main cause of death. [6-14]

Increasing demographic changes worldwide in elderly populations along with exponential rises in chronic conditions will most likely place greater social and fiscal demands on existing clinical, health and social services. [15] To ensure that mortality and survival rates are more precisely captured for these chronic conditions, the relative contributions different diseases have upon survival and mortality need to be more accurately measured. The challenge is to ensure that more reliable data are recorded to allow for more efficient planning for healthcare services and clinical interventions. Parkinson's disease (PD) is a progressive neurodegenerative disease strongly associated with increased mortality and lower life expectancy than the general population. [16] In addition to the motor symptoms of PD, many patients often live with a significant number of other non-motor conditions which contribute to the symptomatology of the disease. [17-22] In particular, dementia occurs frequently in the elderly PD patient and has been shown to be a strong predictor for increased mortality. [23-33] This most probably has implications for the quality of death certification, which in previous investigations has been found to be inconsistent, under recorded or an inaccurate record of the cause of death in patients. [16,34-37] The methodological design of previous investigations, where cohorts have been drawn from clinical populations or pharmaceutical trials alone may partially explain the variability between studies.[38-40] Only a small number of investigations have employed prospective community study methods to ascertain the utility of death certification in PD, and furthermore few have included a comparison control group.

This investigation is a report of the outcomes from a community cohort of PD patient and controls (without neurological disease) who have been regularly followed over the past 18 years in the county of Denbighshire in the United Kingdom. It aims firstly to examine the reported cause and quality of death certification in

1
2
3 these cohorts. Secondly, it will explore if PD and or dementia are
4 reported as a cause or underlying cause of death on certificates.
5 Thirdly, the demographic, motor and non-motor symptoms of PD
6 will be explored to establish if they are associated or predictive with
7 an increased risk of mortality.

8 **Methods**

9 **Subjects**

10
11
12 The patient and control recruitment methodology has been
13 described in greater depth in previous reports [25,41]. In brief,
14 between December 1994 and January 1997, employing multiple
15 sources of ascertainment we recruited newly diagnosed PD
16 patients and patients with an existing diagnosis of probable PD
17 based upon the UKPDS brain bank criteria. [42] General
18 practitioner (GP) records (n=74) in a defined Area of North Wales
19 (Denbighshire), were employed to identify individuals in receipt of a
20 defined group of anti-parkinsonian drugs, which included
21 Levodopa, monomine-oxidase-B inhibitors, dopamine agonists and
22 anti-muscarinic drugs. Additionally, hospital records were examined
23 and patients who were not on active but known to medical services
24 were also ascertained. In total, 402 patients were identified, of
25 whom 213 fulfilled criteria for clinically probable PD patients (n=
26 213). Of the original PD cohort, 25 died before they could be
27 consented into the investigation, 13 withdrew consent and the
28 remaining patients (n = 9) were lost to follow-up. This left at study
29 entry 166 probable PD patients for follow-up from December 1997
30 to January 2015.

31
32 The control cohort was randomly drawn from two GP practices
33 within the same geographical area of the PD cohort within the
34 same time frame. The controls were matched for sex and age to
35 PD patients (\pm 3 years), were not known to have a diagnosis of
36 clinically probable PD, parkinsonism, Alzheimer's or other
37 dementia, stroke, neurological disorder, not in receipt of
38 psychoactive drugs and did not have a known psychiatric, alcohol
39 or substance abuse history. A total of 164 controls were invited to
40 participate in the study, of whom 42 subsequently declined to
41 participate and a further six withdrew consent at a later date. Upon
42 initial baseline screening, eight were found to have previously
43 suffered from a stroke, two had signs of parkinsonism and four
44 fulfilled criteria for dementia and were excluded from further
45 analysis, leaving a cohort of 102 control subjects.

46 **Clinical assessment.**

47
48
49 The PD and control cohorts demographic details were recorded
50 which included, age, gender, educational attainment, social class,
51 and smoking history. In addition to the demographic details, PD
52 specific variables were also recorded which included, age of
53 diagnosis, duration of symptoms, Hoehn and Yahr staging (H&Y),
54 the UPDRS motor subsection, the 15-item Geriatric Depression
55 Scale (GDS -15), the Cambridge Examination for Mental Disorders
56 of the Elderly (CAMDEX), section B (CAMCOG), the Parkinson's
57

1
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3 disease Activities of Daily Living Scale (PADL) and the health
4 related quality of life (HRQoL) measure the EQ5-D.[43-47] These
5 measures were reassessed at approximately two yearly intervals
6 from the midpoint of the recruitment phase of the cohort assembly.
7 Diagnosis of PD based upon UKPDBB criteria was reassessed
8 (RJM) at review to ensure diagnostic accuracy was maintained.
9 The control cohort screening was also carried out approximately
10 every two years from study entry which included review and
11 updating of demographic variables, and reassessment with the
12 GDS-15, CAMCOG, and EQ5-D. Analysis of the clinical
13 assessments was the most recent prior to a subjects reported
14 death. The diagnosis of dementia for PD and controls was based
15 upon neuropsychological assessment, patient, and carer/informant
16 interviews, along with the application of the Diagnostic and
17 Statistical Manual of Mental disorders fourth edition criteria. [48]

18 19 20 **Death certification collection and evaluation.**

21 Review of hospital and primary care records were employed to
22 ascertain the number of individuals who were deceased. All of the
23 death certificates in this investigation were obtained from the local
24 Births, Deaths, and Marriages central record office for the PD and
25 control cohorts. Primary and underlying cause of death, along with
26 the age of the subject and the age of death are recorded on all
27 certificates in the UK. In addition, all certificates completed by a
28 doctor within the UK and are coded using the ICD-10 system as
29 follows:

30 Ia: Disease or condition leading directly to death.
31 I(b): Other disease or condition, if any, leading to I(a).
32 I(c): Other disease or condition, if any, leading to I(b)
33 II: Other significant conditions that contributing to death but not
34 related to the disease or condition causing it.
35

36 From the information recorded on the death certificates, we
37 grouped primary and underlying causes of death in to nine further
38 categories which were, PD, Sepsis, Dementia, Cerebrovascular,
39 Cardiac, Cancer, Pneumonia, Chronic lung disease, other
40 disorders.
41

42 **Ethical approval:**

43 This study was approved by the North Wales Research and ethics
44 committee (Central).
45

46 **Statistics.**

47
48 The standardized mortality (SMR) was calculated as the ratio of
49 observed deaths in the study group to expected deaths by
50 employing age and gender specific morality rates for each year of
51 the investigation, drawn from the UK Office of National Statistics
52 interim life tables.
53

54 Descriptive statistics (mean, SD, median) were used for continuous
55 variables, whereas categorical variables were described as
56 percentages of subjects in each group. Student t-tests, the chi-
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3 square test, and Univariate logrank statistics were employed to
4 examine between-group differences and between observed and
5 expected survival curves (all values two-tailed, $p < 0.05$). The
6 survival time of subjects was calculated from the date of baseline
7 examination. The Kaplan-Meier estimates were used to calculate
8 the observed survival curves. Cox proportional (PH) hazards
9 analysis was employed to investigate the effect of several variables
10 upon the time a specified event takes to happen, which in the
11 current study was death. To satisfy the assumptions for the PH
12 modelling, visual inspections of the residuals against the
13 independent variable were made. This was carried out by plotting
14 the cumulative survival function for each group against time and
15 observing if the lines were parallel, proportional hazard was
16 assumed. In addition, the -2 log likelihood ratio statistic was
17 employed to determine how well the model (pattern of covariates)
18 fitted the obtained data. The PH model covariates act as factors
19 multiplying the hazard rate, which is the probability of experiencing
20 the event which in this study is death. Covariates included in the
21 PH model included, age at study entry, age at death, gender, motor
22 function, mood, HRQoL, and cognitive function. The Hazard Ratio
23 (HR) reported in this study provides an estimate of the relative risk.

24
25 All data were analysed with the SPSS statistical package version
26 19. [49] The relative risk (RR) and 95% confidence interval (CI)
27 were calculated using the Altman formula and MedCalc software.
28 [50,51]

29 **Results**

30
31 From baseline to the study end date (30/01/2015), 158/166 (96%)
32 of the PD and 34/102 (33%) of the control cohorts were decedents.
33 In Table 1 the demographic and clinical outcomes of the PD and
34 control cohorts are shown. Figure 1 illustrates the Kaplan-Meier
35 survival curves for all cause mortality in the PD and control cohorts.
36 The SMR for the whole PD cohort was 1.82 (95% CI: 1.55 – 2.13).
37 A sub group analysis between new cases of PD ($n = 80$) identified
38 during the cases ascertainment phase of the investigation and
39 existing cases of PD ($n = 78$) revealed no excess mortality between
40 the groups ($p = 0.186$) despite the varying disease duration. By 18
41 years the cumulative survival in the PD cohort (figure 1), was
42 approximately 5% and 67% in the control cohort. The mortality risk
43 controlled for age and gender was significantly higher risk in the PD
44 cohort (HR 7.89, $p = 0.0001$). Older age at entry into the current
45 study was predictive of an increased risk of mortality in both
46 cohorts (PD: HR 1.06, $p = 0.0001$; Control: HR 1.09, $p = 0.009$).
47 There were no statistical differences found between the PD and
48 control cohorts age at death (PD cohort 80.7 (7.1), Control cohort
49 81.9(6.3); $p = 0.552$). The strongest predictor associated with
50 mortality in the PD cohort after controlling for age and gender was
51 worsening motor symptoms (HR 1.06, $p < 0.01$).
52

53 As a primary cause of death (Part 1a on UK death certificates), PD
54 was recorded in just over 4% of the cohort. In sections 1b and 1c
55 (conditions substantially contributing to death), PD was reported in
56 24% and 6% of cases respectively. In section II of the death
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certificates (co-morbid conditions substantially contributing to death); PD was reported in 19% of cases. Overall, PD as a contributing factor in the cause of death, was not reported anywhere on 75/158 (47%) of the PD cohort's certificates. The primary cause of death for the PD and control cohorts is shown in Table 2. The most common causes of death reported within the PD cohort were pneumonia (53%), followed by cardiac related deaths (21%). The most frequently recorded cause of death within the control cohort were cardiac disease (26%), cancer (24%), and pneumonia (18%). A comparison between the PD and Control cohorts revealed that the PD cohort were nearly three times more likely to have pneumonia recorded as a primary cause of death (RR, 2.94, 95% CI 1.40-6.19). Controlling for patients and controls with dementia still revealed a higher risk of mortality in PD for pneumonia (RR, 2.03, 95% CI 1.34-3.6). The controls compared to the PD cohort had over a threefold increased risk of having a cancer related disorder recorded as a primary or underlying cause of death (RR, 3.72, 95% CI 1.58 -8.72). Examining the smoking history between the two cohorts found no significant differences with the frequency of current or former smokers ($p = 0.39$), nor were there differences in the cancer risk observed between the PD and controls cohorts who never smoked ($p = 0.75$). However, significantly more of the controls who were smokers prior to their death had cancer recorded as a primary or secondary cause of death ($p < 0.025$).

Disease progression within the PD cohort was significantly associated with a worsening HRQoL at death ($p < 0.0001$). When compared to the controls, HRQoL was significantly poorer for the PD cohort ($p < 0.001$). At the time of death, 83/158 (52%) of the PD and 9/34 (26%) of the control cohorts were living in institutional care ($p < 0.003$). Overall, the PD cohort decedents had a threefold increased probability to be living in institutional care at death (RR 3.23, 95% CI 1.4-7.41). Controlling for age and duration of illness, the PD cohort living in institutional were also more likely to be demented (RR 2.7 (95% CI 1.21- 5.76). In contrast to the PD cohort, the control decedent's place of death was more likely to be in hospital (RR, 1.97, 1.48-2.62).

As a primary or underlying cause of death, dementia was underreported on both the PD and control certificates. Although 144/158 (91%) of the PD cohort had a diagnosis of dementia before their deaths, it was reported in only 14/144 of certificates. Similarly, only two of the control cohort had dementia recorded anywhere as a primary or underlying cause of death. Upon review however, a further four at the time of death had a confirmed diagnosis of dementia.

Discussion.

This investigation reports the cause of death recorded on the death certificates of PD and age matched control cohorts in Denbighshire

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3 in the UK. We have previously reported that the life expectancy and
4 average age at death in this PD cohort is much lower than the
5 general population. [16] In the current study the overall SMR for our
6 PD cohort was 1.82, indicating an excess mortality. This is similar
7 to previous investigations where the SMR has been reported to
8 range from 0.9 to 3.8 [16] However, recent community based
9 incident cohort and incident clinical cohort investigations have
10 reported lower SMR's of 1.29 (95% CI, 0.97-1.61), and 1.39 (95%
11 CI, 1.10.-1.50), suggesting a moderate increase mortality
12 compared to the general population. [16,52] The shorter duration of
13 PD diagnosis, lower number of recorded deaths and shorter follow-
14 up period compared with the current investigation may partially
15 explain these differences the current and previously reported UK
16 investigation. In addition the other European investigation was
17 limited by the retrospective analysis of a data set from 1978-1998
18 and recruitment solely from a clinical population.

19
20 Overall death certification and clinical research data appear to
21 provide quite disparate mortality data in PD. Although our PD
22 cohort had confirmed UKPDSBB criteria for probable PD, as a
23 primary cause of death (Part 1a), it was recorded in just in over 4%
24 of the cohort. A further 30% had PD recorded in parts 1b and c of
25 their death certificates, and on Part II of certificates it was recorded
26 in a further 19% of cases. Overall, PD was not cited anywhere on
27 47% of the death certificates, which falls approximately midway
28 with previous certification studies of between 14–70%. [16,34-37]
29 The disparity reported between studies is most likely evidence of
30 the differing methodologies employed such as, populations drawn
31 from pharmaceutical trials alone, clinical samples, or retrospective
32 case or chart record analysis.

33
34 Pneumonia was the most cited primary cause of death (52%), in
35 the current study. This observation has also been frequently
36 reported in other investigations. [16,52] Patients with PD,
37 particularly as they become frailer with the progression of their
38 illness, are at greater risk for pulmonary complications, due to
39 obstructive ventilation dysfunction, upper airway dysfunction, and
40 weakened strength of respiratory muscles. [53-55] The most
41 frequently reported other causes of death were cardiovascular
42 disease (21%), cerebrovascular disease (8%) and malignancy
43 (6%).

44
45 This is the first study to our knowledge to describe underreporting
46 of dementia as a primary, or underlying cause of death in a
47 community based PD cohort. We have previously reported in this
48 cohort the high prevalence of dementia of around 90%. [56] Upon
49 review of the decedents death certificates, we found that less than
50 10% had any mention of dementia as an immediate or underlying
51 cause of death. Previous general population investigations have
52 also shown that rates of certification mentioning dementia as a
53 main or underlying cause of death have been consistently under
54 reported. [57-61] This perhaps is because certification tends to
55 focus upon the immediate cause of death and does not really
56 capture the multiple factors that contribute to death, particularly
57 with elderly individuals with multiple co-morbidity.

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4 This investigation found that the PD cohort were more likely than
5 the controls to be living in a long term care setting before death.
6 This may be a reflection of the duration, nature and the type of
7 burden PD places upon relatives, especially those who have
8 physical frailty themselves. Caring within the home setting may
9 therefore become more impracticable and thus possibly
10 precipitates entry into institutional care. The proportion of deaths in
11 long term care amongst the PD cohort was also significantly higher
12 than the control cohort. A recent study reported wide variations in
13 the place of death of people with PD throughout the world,
14 concluding that individual preference, social and socioeconomic
15 circumstances; cultural, organisation and provision of health and
16 palliative care all contribute to some extent the place of death. [62]

17
18 In common with previous mortality investigations we found fewer
19 recorded cancer deaths within the PD cohort. [63] We did not
20 observe differences in the current or past smoking history
21 frequency between our cohorts. Similarly no differences were
22 revealed between the cohorts and cancer risk in those who had
23 never smoked. There were no differences seen in the types of
24 cancer type on death certificates compared to smokers and non-
25 smokers. However, in the current smoker groups prior to death,
26 significantly more cancer associated deaths were recorded in the
27 controls compared to the PD cohort. A possible explanation for this
28 disparity may be that mutations of the PARK2 (Parkin) gene found
29 in 6-8% of PD patients, may act in some cancers as a tumour
30 suppressor proteins. [64] The absence or mutation of the Parkin
31 gene is found in several tumour types, suggesting that the
32 mechanisms of cell death in PD may play a role in the inhibition or
33 formation of some cancers. [64,65] The decreased risk of mortality
34 from cancer has also been reported in other neurodegenerative
35 disease including Alzheimer's, Huntington's disease and in
36 populations where mild to moderate with cognitive impairment has
37 also been observed. [66-69] Further studies are needed to explore
38 the associations, risks, possible genetic markers and underlying
39 mechanisms in PD and other neurodegenerative conditions, to
40 improve and identify and understand the role of cell death and its
41 decreased cancer risk.

42
43 We would caution the message often given to PD patients that they
44 die with, rather than die of the condition. The non-motor features of
45 PD such as dementia and autonomic dysfunction are frequently
46 observed in all stages of the disease and most likely make a
47 significant contribution to mortality.[70] One recent investigation
48 reported that autonomic dysfunction and dementia in PD was
49 predictive of increased mortality particularly in patients with
50 orthostatic hypotension (OH).[71] Another meta-analysis which
51 explored the association with OH and mortality in general
52 populations also concluded that OH may confer a greater risk (RR,
53 1.40) for mortality. [72] The association between the non-motor
54 features of PD disease and mortality needs further research to
55 understand and determine if these are causal or not.
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3 This study's strengths are the robust follow-up over an 18-year
4 period of a community based cohort all of whom fulfilled criteria for
5 PD and diagnostic re-evaluation was reviewed regularly over this
6 period to ensure diagnostic accuracy. The repeat measure design
7 of the study also allowed us to control for demographics, and motor
8 and non-motor symptomatology. The limitations of the study are
9 that the PD cohort had a mix of prevalent and incident cases, thus
10 possibly over estimating the possible causal associations with
11 mortality. However, controlling for prevalent and incident cases in
12 our analysis did not reveal any between group significant
13 differences. Our control cohort was selected carefully in terms of
14 age, gender, and disease exposure and may not representative of
15 the general population. We endeavoured to reduce this potential
16 bias by randomly selecting controls from general practitioner lists
17 within defined catchment area as the PD cohort. However,
18 excluding controls with known neurological, psychiatric illness and
19 possibly healthier general health may be a potential source of error.
20 The ideal comparison group in a cohort study would be exactly the
21 same as the cohort of interest, except that they would not have the
22 condition under investigation. In older populations, the selection of
23 any control group is often a compromise in ensuring that the control
24 group differs enough with respect to the condition of interest, yet
25 are similar as possible to explore what other factors influence the
26 outcome under investigation. We believe that our selection of
27 controls without neurological or psychiatric disease allowed us to
28 control for confounding factors in the analysis in both cohorts that
29 would not have been possible in the general population.

30
31 In light of our findings we feel that the current methods of capturing
32 the cause of death by certification will significantly underestimate
33 the true population burden of PD. The under reporting of dementia
34 as an underlying cause of death in this cohort in addition to PD, also
35 suggests that the interpretation of and quality of mortality data
36 currently is not a valid or reliable source of data. Furthermore we
37 would admonish the use of mortality statistics alone to plan for
38 future service provision in this patient population.

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For peer review only

Table 1:
Demographic and clinical outcomes (Means, *standard deviations*)
of the PD and control cohorts

	Parkinson's disease	Control	<i>p</i> < 0.05
Gender (female %)	44%	41%	NS
Age (entry into study)	74.2 (8.6)	74.8 (6.6)	NS
Age at death	80.7 (7.1)	81.9 (6.3)	NS
Institutional care %	52%	30%	0.003
Place of death (Hospital)	37%	74%	0.002
EQ-5D (Weighted health)	0.58 (0.36)	0.79 (0.28)	0.001
EQ-5D (VAS %) [†]	55 (16.5)	77 (17.6)	0.001
Onset of PD	67.3 (10.7)	-----	-----
Duration of PD	13.2 (8.8)	-----	-----
UPDRS (motor section)	27.9 (11.7)	-----	-----
H & Y	2.9 (0.74)	-----	-----
PADL	3.1 (1.1)	-----	-----

[†] VAS = EQ-5D Visual Analogue Scale.

Table 2.

Primary cause of death (Part 1a death certificates) reported for the PD (n =158) and control (n =34) cohorts.

	Parkinson's disease	Control
Pneumonia	84 (53.2%)	6 (17.6%)
Cardiac	33 (20.9%)	9 (26.5%)
Cancer	10 (6.3%)	8 (23.5%)
Cerebrovascular	12 (7.6%)	4 (11.8%)
Parkinson's disease	7 (4.4%)	0
Other*	12	7

* Other includes Sepsis; Dementia; Immobility; Chronic obstructive pulmonary disease; Old age; Fracture neck of Femur; Multi-organ failure; Motor Neurone disease.

Figure 1.
Kaplan-Meier survival curves for all cause mortality in the PD and control cohorts

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2
3 **Funding:** This research received no specific grant from any funding
4 agency in the public, commercial or not-for-profit sectors.
5

6 **Contributors:** PH and RJM conceived and designed the study,
7 collected the data, and managed the database. PH managed the
8 database, contributed to data cleaning, performed the statistical
9 analyses. PH and RJM contributed to interpretation of the data. PH
10 and RJM wrote the manuscript. All authors critically reviewed the
11 manuscript and approved the final version to be published.
12

13 **Competing interests:** None declared.
14

15 **Patient consent:** All participants gave their informed and written
16 consent on participation.
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18 **Data sharing statement:** No additional data available.
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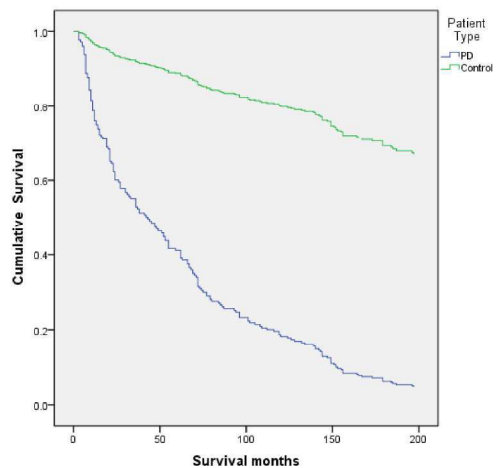


Figure 1.
Kaplan-Meier survival curves for all cause mortality in the PD and control cohorts

297x420mm (300 x 300 DPI)

STROBE 2007 (v4) checklist of items to be included in reports of observational studies in epidemiology*
Checklist for cohort, case-control, and cross-sectional studies (combined)

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(a) Indicate the study’s design with a commonly used term in the title or the abstract	1
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3
Objectives	3	State specific objectives, including any pre-specified hypotheses	3,4
Methods			
Study design	4	Present key elements of study design early in the paper	4
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	4
Participants	6	(a) <i>Cohort study</i> —Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up <i>Case-control study</i> —Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls <i>Cross-sectional study</i> —Give the eligibility criteria, and the sources and methods of selection of participants	4
		(b) <i>Cohort study</i> —For matched studies, give matching criteria and number of exposed and unexposed <i>Case-control study</i> —For matched studies, give matching criteria and the number of controls per case	4
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	4
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	4,5
Bias	9	Describe any efforts to address potential sources of bias	5,6,8
Study size	10	Explain how the study size was arrived at	n/a
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	n/a
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	5
		(b) Describe any methods used to examine subgroups and interactions	5
		(c) Explain how missing data were addressed	n/a
		(d) <i>Cohort study</i> —If applicable, explain how loss to follow-up was addressed <i>Case-control study</i> —If applicable, explain how matching of cases and controls was addressed	n/a

		<i>Cross-sectional study</i> —If applicable, describe analytical methods taking account of sampling strategy	
		(e) Describe any sensitivity analyses	n/a
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	5
		(b) Give reasons for non-participation at each stage	n/a
		(c) Consider use of a flow diagram	--
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	5
		(b) Indicate number of participants with missing data for each variable of interest	n/a
		(c) <i>Cohort study</i> —Summarise follow-up time (eg, average and total amount)	5,6
Outcome data	15*	<i>Cohort study</i> —Report numbers of outcome events or summary measures over time	5,6
		<i>Case-control study</i> —Report numbers in each exposure category, or summary measures of exposure	5,6
		<i>Cross-sectional study</i> —Report numbers of outcome events or summary measures	--
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	5,6
		(b) Report category boundaries when continuous variables were categorized	5,6
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	5,6
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	5,6
Discussion			
Key results	18	Summarise key results with reference to study objectives	6
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	8
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	8
Generalisability	21	Discuss the generalisability (external validity) of the study results	6-8
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	9

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at www.strobe-statement.org.

BMJ Open

Mortality and the quality of death certification in a cohort of Parkinson's disease patients and matched controls in North Wales, United Kingdom at 18-years: a community based cohort study.

Journal:	<i>BMJ Open</i>
Manuscript ID	bmjopen-2017-018969.R3
Article Type:	Research
Date Submitted by the Author:	20-Dec-2017
Complete List of Authors:	Hobson, Peter; Academic Unit Meara, Jolyon; Academic Unit
Primary Subject Heading:	Neurology
Secondary Subject Heading:	Epidemiology, Neurology
Keywords:	Parkinson-s disease < NEUROLOGY, Mortality, Death certification, Dementia < NEUROLOGY

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Manuscripts

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3 Mortality and the quality of death certification in a cohort of
4 Parkinson's disease patients and matched controls in North Wales,
5 United Kingdom at 18-years: a community based cohort study.
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26 Keywords:
27 Parkinson's disease, Mortality, Death certification, Dementia
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29 Word count: 3685
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Abstract

Objective: This investigation reports the cause and the quality of death certification in a community cohort of Parkinson's disease (PD) patients and controls at 18 years.

Setting: Denbighshire North Wales United Kingdom (UK).

Participants: The community based cohorts consisted of 166 PD and 102 matched controls.

Primary outcomes: All-cause mortality was ascertained at 18-years by review of hospital, primary care records and examination of death certificates obtained from the UK General Register Office. Mortality Hazard Ratios were estimated using Cox proportional regression controlling for covariates including, age at study entry, age at death, gender, motor function, mood, health related quality of life (HRQoL), and cognitive function.

Results: After 18-years, 158(95%) of the PD cohort and 34(33%) of the control cohort had died. Compared to the general UK population, the PD cohort had a higher risk of mortality (standard mortality rate, 1.82, 95% CI: 1.55 – 2.13). As the primary or underlying cause of death, PD was not reported in 75/158 (47%) of the death certificates. In addition, although 144/158 (91%) of the PD cohort had a diagnosis of dementia, this was reported in less than 10% of death certificates. The main cause of death reported in the PD cohort was pneumonia (53%), followed by cardiac related deaths (21%). Compared to controls, PD patients had a greater risk of pneumonia (2.03, 95% CI, 1.34-3.6), poorer HRQoL and more likely to reside in institutional care at death ($p < 0.01$).

Conclusion: This investigation found that PD was associated with an excess risk of mortality compared to the general population. However, PD as a primary or underlying cause of death recorded on certificates was found to be suboptimal. This suggests that the quality of mortality statistics drawn from death certificates alone is not a valid or reliable source of data.

Strengths and limitations

- Community based longitudinal follow-up cohort design.
- All patients fulfilled diagnostic criteria for Parkinson's disease and or dementia.
- Baseline and subsequent repeat measure data capture allowed analysis for predictive outcomes.
- The cohort included prevalent and new cases Parkinson's disease. Although the varying disease duration of the Parkinson's disease cohort is a possible source of bias, we found no differences between the two groups survival.
- The control cohort included subjects without known neurological conditions and thus may have intruded bias in the outcome comparisons with the Parkinson's disease patients.

Introduction

Data drawn from death certificates is often employed by epidemiological, public health and research scientists to capture the incidence, prevalence and mortality in populations. In addition, these statistics are often utilized in the evaluation of public health interventions, setting priorities for medical research and health services, the planning of health services, and the clinical assessment of the effectiveness of those services. [1-3] The introduction of the revised International Classification of Diseases (ICD) system in 2001 aim was to improve the accuracy in the reported cause of death, where underlying conditions, mentioned in Part 1 or 2 of death certification take priority over others. [4,5] The underlying principle for this is that reporting of multiple causes of death should provide a better description of a particular disease or condition, allowing for more effective and meaningful data capture. The reliability of statistical information extracted from death certificates remains uncertain, where for example, rather than the underlying chronic condition being reported, a secondary cause of death is often reported as the main cause of death. [6-14]

The projected elderly population demographic changes worldwide, along with exponential rises in chronic conditions will most likely place greater social and fiscal demands upon existing clinical, health and social services. [15] To ensure that mortality and survival rates are more precisely captured for these chronic conditions, the relative contributions different diseases have upon survival and mortality need to be more accurately measured. The challenge is to ensure that any statistical collected is valid and reliable enough to allow for more efficient planning for healthcare services and clinical interventions. Parkinson's disease (PD) is a progressive neurodegenerative disease strongly associated with increased mortality and lower life expectancy than the general population. [16] In addition to the motor symptoms of PD, many patients often live with a significant number of other non-motor conditions, which contribute, to the symptomatology of the disease. [17-22] In particular, dementia occurs frequently in the elderly PD patient and has been shown to be a strong predictor for increased mortality. [23-33] This most probably has implications for the quality of death certification, which in previous investigations has been found to be inconsistent, under recorded or an inaccurate record of the cause of death in patients. [16,34-38] The methodological design of previous investigations, where cohorts have been drawn from clinical populations or pharmaceutical trails alone may partially explain the variability between studies.[39-40] Only a small number of investigations have employed prospective community study methods to ascertain the utility of death certification in PD, and furthermore few have included a comparison control group.

This investigation is a report of the outcomes from a community cohort of PD patient and controls (without neurological disease) who have been regularly followed over the past 18 years in the county of Denbighshire in the United Kingdom. It aims firstly to examine the reported cause and quality of death certification in these cohorts. Secondly, it will explore if PD and or dementia are

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3 reported as a cause or underlying cause of death on certificates.
4 Thirdly, the demographic, motor and non-motor symptoms of PD
5 will be explored to establish if they are associated or predictive with
6 an increased risk of mortality.

7 8 **Methods**

9 10 **Subjects**

11 The patient and control recruitment methodology has been
12 described in greater depth in previous reports [25,41]. In brief,
13 between December 1994 and January 1997, employing multiple
14 sources of ascertainment we recruited newly diagnosed PD
15 patients and patients with an existing diagnosis of probable PD
16 based upon the UKPDS brain bank criteria. [42] General
17 practitioner (GP) records (n=74) in a defined Area of North Wales
18 (Denbighshire), were employed to identify individuals in receipt of a
19 defined group of anti-parkinsonian drugs, which included
20 Levodopa, monomine-oxidase-B inhibitors, dopamine agonists and
21 anti-muscarinic drugs. Additionally, hospital records were examined
22 and patients who were not on active but known to medical services
23 were also ascertained. In total, 402 patients were identified, of
24 whom 213 fulfilled criteria for clinically probable PD patients (n=
25 213). Of the original PD cohort, 25 died before they could be
26 consented into the investigation, 13 withdrew consent and the
27 remaining patients (n = 9) were lost to follow-up. This left at study
28 entry 166 probable PD patients for follow-up from December 1997
29 to January 2015.

31 The control cohort was randomly drawn from two GP practices
32 within the same geographical area of the PD cohort within the
33 same time frame. The controls were matched for sex and age to
34 PD patients (\pm 3 years), were not known to have a diagnosis of
35 clinically probable PD, parkinsonism, Alzheimer's or other
36 dementia, stroke, neurological disorder, not in receipt of
37 psychoactive drugs and did not have a known psychiatric, alcohol
38 or substance abuse history. One hundred and sixty four controls
39 were invited to participate in the study, of whom 42 subsequently
40 declined to participate and a further six withdrew consent at a later
41 date. Upon initial baseline screening, eight were found to have
42 previously suffered from a stroke, two had signs of parkinsonism
43 and four fulfilled criteria for dementia and were excluded from
44 further analysis, leaving a cohort of 102 control subjects.

45 46 **Clinical assessment.**

47 The PD and control cohorts demographic details were recorded
48 which included, age, gender, educational attainment, social class,
49 and smoking history. In addition to the demographic details, PD
50 specific variables were also recorded which included, age of
51 diagnosis, duration of symptoms, Hoehn and Yahr staging (H&Y),
52 the UPDRS motor subsection, the 15-item Geriatric Depression
53 Scale (GDS -15), the Cambridge Examination for Mental Disorders
54 of the Elderly (CAMDEX), section B (CAMCOG), the Parkinson's
55 disease Activities of Daily Living Scale (PADL) and the health
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3 related quality of life (HRQoL) measure the EQ5-D. [43-47] These
4 measures were reassessed at approximately two yearly intervals
5 from the midpoint of the recruitment phase of the cohort assembly.
6 Diagnosis of PD based upon UKPDBB criteria was reassessed
7 (RJM) at review to ensure diagnostic accuracy was maintained.
8 The control cohort screening was also carried out approximately
9 every two years from study entry, which included review and
10 updating of demographic variables, and reassessment with the
11 GDS-15, CAMCOG, and EQ5-D. Analysis of the clinical
12 assessments was the most recent prior to a subjects reported
13 death. The diagnosis of dementia for PD and controls was based
14 upon neuropsychological assessment, patient, and carer/informant
15 interviews, along with the application of the Diagnostic and
16 Statistical Manual of Mental disorders fourth edition criteria. [48]
17

18 **Death certification collection and evaluation.**

19
20 Review of hospital and primary care records were employed to
21 ascertain the number of individuals who were deceased. All of the
22 death certificates in this investigation were obtained from the local
23 Births, Deaths, and Marriages central record office for the PD and
24 control cohorts. Primary and underlying cause of death, along with
25 the age of the subject and the age of death are recorded on all
26 certificates in the UK. In addition, all certificates completed by a
27 doctor within the UK and are coded using the ICD-10 system as
28 follows:

29 Ia: Disease or condition leading directly to death.
30 I(b): Other disease or condition, if any, leading to I(a).
31 I(c): Other disease or condition, if any, leading to I(b)
32 II: Other significant conditions that contributing to death but not
33 related to the disease or condition causing it.
34

35 From the information recorded on the death certificates, we
36 grouped primary and underlying causes of death in to nine further
37 categories which were, PD, Sepsis, Dementia, Cerebrovascular,
38 Cardiac, Cancer, Pneumonia, Chronic lung disease, other
39 disorders.
40

41 **Ethical approval:**

42 This study was approved by the North Wales Research and ethics
43 committee (Central).
44

45 **Statistics.**

46
47 The age and gender specific standardized mortality ratios (SMR)
48 were calculated by dividing the observed deaths in each cohort by
49 expected numbers of deaths. This is calculated by multiplication of
50 the numbers of person's-years for each 5-year age group, gender
51 and year by the corresponding general population age group,
52 gender and year, drawn from the UK Office of National Statistics
53 interim life tables 2016.
54

55 Descriptive statistics (mean, SD, median) were used for continuous
56 variables, whereas categorical variables were described as
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percentages of subjects in each group. Student t-tests, the chi-square test, and Univariate logrank statistics were employed to examine between-group differences and between observed and expected survival curves. The Relative Risk (RR) was calculated by dividing the probability of an event occurring for PD cohort, divided by the probability of an event occurring for the control cohort. The survival time of subjects was calculated from the date of baseline examination for each subject. The Kaplan-Meier estimates were used to calculate the observed survival curves. Cox proportional hazards (PH) analysis was used to investigate the effect of several variables upon the time a specified event takes to happen. To satisfy the assumptions for the PH modelling, visual inspections of the Kaplan-Meier curves were made. The Cox PH modelling was also employed to calculate the hazard ratio's (HR) and the 95% confidence intervals (CIs) for differences between groups defined by demographic and clinical features defined at baseline. The PH model covariates act as factors multiplying the (HR), which is the probability of experiencing the event, which in this study is death. Covariates included in the PH model included, age at study entry, age at death, gender, motor function, mood, HRQoL, and cognitive function. The Hazard Ratio (HR) reported in this study provides an estimate of the relative risk.

All data were analysed with the SPSS statistical package version 19 and the RR and 95% CIs were calculated using the Altman formula and MedCalc software. [49-51] The level of significance was set at as $p < 0.05$.

Results

From baseline to the study end date (30/01/2015), 158/166 (96%) of the PD and 34/102 (33%) of the control cohorts were decedents. In Table 1 the demographic and clinical outcomes of the PD and control cohorts are shown. Figure 1 illustrates the Kaplan-Meier survival curves for all cause mortality in the PD and control cohorts. The SMR for the whole PD cohort was 1.82 (95% CI: 1.55 – 2.13). A sub group analysis between new cases of PD ($n = 80$) identified during the cases ascertainment phase of the investigation and existing cases of PD ($n = 78$) revealed no excess mortality between the groups ($p = 0.186$) despite the varying disease duration. By 18 years the cumulative survival in the PD cohort (figure 1), was approximately 5% and 67% in the control cohort. The mortality risk controlled for age and gender was significantly higher risk in the PD cohort (HR 7.89, $p = 0.0001$). Older age at entry into the current study was predictive of an increased risk of mortality in both cohorts (PD: HR 1.06, $p = 0.0001$; Control: HR 1.09, $p = 0.009$). There were no statistical differences found between the PD and control cohorts age at death (PD cohort 80.7 (7.1), Control cohort 81.9(6.3); $p = 0.552$). The strongest predictor associated with mortality in the PD cohort after controlling for age and gender was worsening motor symptoms (HR 1.06, $p < 0.01$).

As a primary cause of death (Part 1a on UK death certificates), PD was recorded in just over 4% of the cohort. In sections 1b and 1c (conditions substantially contributing to death), PD was reported in

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3 24% and 6% of cases respectively. In Section II of the death
4 certificates (co-morbid conditions substantially contributing to
5 death); PD was reported in 19% of cases. Overall, PD as a
6 contributing factor in the cause of death, was not reported
7 anywhere on 75/158 (47%) of the PD cohort's certificates. The
8 primary cause of death for the PD and control cohorts is given in
9 Table 2 . The most common causes of death reported within the
10 PD cohort were pneumonia (53%), followed by cardiac related
11 deaths (21%). The most frequently recorded cause of death within
12 the control cohort was cardiac disease (26%), cancer (24%), and
13 pneumonia (18%). A comparison between the PD and Control
14 cohorts revealed that the PD cohort were nearly three times more
15 likely to have pneumonia recorded as a primary cause of death
16 (RR, 2.94, 95% CI 1.40-6.19). Controlling for patients and controls
17 with dementia still revealed a higher risk of mortality in PD for
18 pneumonia (RR, 2.03, 95% CI 1.34-3.6). The controls compared to
19 the PD cohort had over a threefold increased risk of having a
20 cancer related disorder recorded as a primary or underlying cause
21 of death (RR, 3.72, 95% CI 1.58 -8.72). Examining the smoking
22 history between the two cohorts found no significant differences
23 with the frequency of current or former smokers ($p = 0.39$), nor
24 were differences in cancer risk observed between the PD and
25 controls cohorts who never smoked ($p = 0.75$). However,
26 significantly more of the controls who were smokers prior to their
27 death had cancer recorded as a primary or secondary cause of
28 death ($p < 0.025$).

29
30 Disease progression within the PD cohort was significantly
31 associated with a worsening HRQoL at death ($p < 0.0001$). When
32 compared to the controls, HRQoL was significantly poorer for the
33 PD cohort ($p < 0.001$). At the time of death, 83/158 (52%) of the PD
34 and 9/34 (26%) of the control cohorts were living in institutional
35 care ($p < 0.003$). Overall, the PD cohort decedents had a threefold
36 increased probability to be living in institutional care at death (RR
37 3.23, 95% CI 1.4-7.41). Controlling for age and duration of illness,
38 the PD cohort living in institutional were also more likely to be
39 demented (RR 2.7 (95% CI 1.21- 5.76). In contrast to the PD
40 cohort, the control decedent's place of death was more likely to be
41 in hospital (RR, 1.97, 1.48-2.62).

42
43 As a primary or underlying cause of death, dementia was
44 underreported on both the PD and control certificates. Although
45 144/158 (91%) of the PD cohort had a diagnosis of dementia
46 before their deaths, it was reported in only 14/144 of certificates.
47 Similarly, only two of the control cohort had dementia recorded
48 anywhere as a primary or underlying cause of death. Upon review
49 however, a further four at the time of death had a confirmed
50 diagnosis of dementia.

Discussion.

This investigation reports the cause of death recorded on the death certificates of PD and age matched control cohorts in Denbighshire in the UK. We have previously reported that the life expectancy and average age at death in this PD cohort is much lower than the general population. [16] In the current study the overall SMR for our PD cohort was 1.82, indicating an excess mortality. This is similar to previous investigations where the SMR has been reported to range from 0.9 to 3.8 [16] However, recent community based incident cohort and incident clinical cohort investigations have reported lower SMR's of 1.29 (95% CI, 0.97-1.61), and 1.39 (95% CI, 1.10.-1.50), suggesting a moderate increase mortality compared to the general population. [16,52] The shorter duration of PD diagnosis, lower number of recorded deaths and shorter follow-up period compared with the current investigation may partially explain these differences the current and previously reported UK investigation. In addition, the other European investigation was limited by the retrospective analysis of a data set from 1978-1998 and recruitment solely from a clinical population.

Overall death certification and clinical research data appear to provide disparate mortality data in PD. Although our PD cohort had confirmed UKPDSBB criteria for probable PD, as a primary cause of death (Part 1a), it was recorded in just in over 4% of the cohort. A further 30% had PD recorded in parts 1b and c of their death certificates, and on Part II of certificates it was recorded in a further 19% of cases. Overall, PD was not cited anywhere on 47% of the death certificates, which falls approximately midway with previous certification studies of between 14–70%. [16,34-38] The disparity reported between studies is most likely evidence of the differing methodologies employed such as, populations drawn from pharmaceutical trials alone, clinical samples, or retrospective case or chart record analysis.

Pneumonia was the most cited primary cause of death (52%), in the current study. This observation has also been frequently reported in other investigations. [16,52] Patients with PD, particularly as they become frailer with the progression of their illness, are at greater risk for pulmonary complications, due to obstructive ventilation dysfunction, upper airway dysfunction, and weakened strength of respiratory muscles. [53-55] The most frequently reported other causes of death were cardiovascular disease (21%), cerebrovascular disease (8%) and malignancy (6%).

This is the first study to our knowledge to describe underreporting of dementia as a primary, or underlying cause of death in a community based PD cohort. We have previously reported in this cohort the high prevalence of dementia of around 90%. [56] Upon review of the decedents death certificates, we found that less than 10% had any mention of dementia as an immediate or underlying cause of death. Previous general population investigations have also shown that rates of certification mentioning dementia as a main or underlying cause of death have been consistently under

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3 reported. [57-61] This perhaps is because death certification tends
4 to focus upon the immediate cause of death and does not really
5 capture the multiple factors that contribute to death, particularly
6 with elderly individuals with multiple co-morbidity.
7

8 This investigation found that the PD cohort were more likely than
9 the controls to be living in a long term care setting before death.
10 This may be a reflection of the duration, nature and the type of
11 burden PD places upon relatives, especially those who have
12 physical frailty themselves. Caring within the home setting may
13 therefore become impracticable and thus possibly precipitates entry
14 into institutional care. The proportion of deaths in long term care
15 amongst the PD cohort was also significantly higher than the
16 control cohort. A recent study reported wide variations in the place
17 of death of people with PD throughout the world, concluding that
18 individual preference, social and socioeconomic circumstances;
19 cultural, organisation and provision of health and palliative care all
20 contribute to some extent the place of death. [62]
21

22 In common with previous mortality investigations, we found fewer
23 recorded cancer deaths within the PD cohort. [63] We did not
24 observe differences in the current or past smoking history
25 frequency between our cohorts. Similarly, no differences were
26 revealed between the cohorts and cancer risk in those who had
27 never smoked. There were no differences seen in the types of
28 cancer type on death certificates compared to smokers and non-
29 smokers. However, in the current smoker groups, significantly more
30 in cancer associated deaths were recorded in the controls
31 compared to the PD cohort. A possible explanation for this disparity
32 may be that mutations of the PARK2 (Parkin) gene found in 6-8%
33 of PD patients, may act in some cancers as a tumour suppressor
34 proteins. [64] The absence or mutation of the Parkin gene is found
35 in several tumour types, suggesting that the mechanisms of cell
36 death in PD may play a role in the inhibition or formation of some
37 cancers. [64,65] The decreased risk of mortality from cancer has
38 also been reported in other neurodegenerative disease including
39 Alzheimer's, Huntington's disease and in populations where mild to
40 moderate with cognitive impairment has also been observed. [66-
41 69] Further studies are needed to explore the associations, risks,
42 possible genetic markers and underlying mechanisms in PD and
43 other neurodegenerative conditions, to improve and identify and
44 understand the role of cell death and its decreased cancer risk.
45

46 We would caution the message often given to PD patients that they
47 die with, rather than die of the condition. The non-motor features of
48 PD such as dementia and autonomic dysfunction are frequently
49 observed in all stages of the disease and most likely make a
50 significant contribution to mortality.[70] One recent investigation
51 reported that autonomic dysfunction and dementia in PD was
52 predictive of increased mortality particularly in patients with
53 orthostatic hypotension (OH).[71] Another meta-analysis which
54 explored the association with OH and mortality in general
55 populations also concluded that OH may confer a greater risk (RR,
56 1.40) for mortality. [72] The association between the non-motor
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3 features of PD disease and mortality needs further research to
4 understand and determine if these are causal or not.
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7 This study's strengths are the robust follow-up over an 18-year
8 period of a community based cohort all of whom fulfilled criteria for
9 PD and diagnostic re-evaluation was reviewed regularly over this
10 period to ensure diagnostic accuracy. The repeat measure design
11 of the study also allowed us to control for demographics, and motor
12 and non-motor symptomatology. The limitations of the study are
13 that the PD cohort had a mix of prevalent and incident cases, thus
14 possibly over estimating the possible causal associations with
15 mortality. However, controlling for prevalent and incident cases in
16 our analysis did not reveal any between group significant
17 differences. Our control cohort was selected carefully in terms of
18 age, gender, and disease exposure and may not representative of
19 the general population. We endeavoured to reduce this potential
20 bias by randomly selecting controls from general practitioner lists
21 within defined catchment area as the PD cohort. However,
22 excluding controls with known neurological, psychiatric illness and
23 possibly healthier general health may be a potential source of error.
24 The ideal comparison group in a cohort study would be the same
25 as the cohort of interest, except that they would not have the
26 condition under investigation. In older populations, the selection of
27 any control group is often a compromise in ensuring that the control
28 group differs enough with respect to the condition of interest, yet
29 are similar as possible to explore what other factors influence the
30 outcome under investigation. We believe that our selection of
31 controls without neurological or psychiatric disease allowed us to
32 control for confounding factors in the analysis in both cohorts that
33 would not have been possible in the general population.
34

35 **Conclusions.**

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37 In light of our findings, we feel that the current methods of capturing
38 the cause of death from certification alone significantly
39 underestimate the true population burden of PD. The under
40 reporting of dementia as an underling cause of death in this cohort
41 in addition to PD, also suggests that the interpretation of and
42 quality of mortality data currently is not a valid or reliable source of
43 data. Furthermore, we would admonish the use of mortality
44 statistics alone to plan for future service provision in this patient
45 population.
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Figure legend:

Figure 1.
Kaplan-Meier survival curves for all cause mortality in the PD and control cohorts.

Table 1:
Demographic and clinical outcomes (Means, *standard deviations*) of the PD and control cohorts

	Parkinson's disease	Control	<i>p</i> < 0.05
Gender (female %)	44%	41%	NS
Age (entry into study)	74.2 (8.6)	74.8 (6.6)	NS
Age at death	80.7 (7.1)	81.9 (6.3)	NS
Institutional care %	52%	30%	0.003
Place of death(Hospital)	37%	74%	0.002
GDS-15	5.6 (2.2)	3.7 (1.1)	0.001
EQ-5D (Weighted health)	0.58 (0.36)	0.79 (0.28)	0.001
EQ-5D (VAS %) [†]	55 (16.5)	77 (17.6)	0.001
Onset of PD	67.3 (10.7)	-----	-----
Duration of PD	13.2 (8.8)	-----	-----
UPDRS (motor section)	27.9 (11.7)	-----	-----
H & Y	2.9 (0.74)	-----	-----
PADL	3.1 (1.1)	-----	-----

[†] VAS = EQ-%D Visual analogue scale

Table 2.

Primary cause of death (Part 1a death certificates) reported for the PD (n =158) and control (n =34) cohorts.

	Parkinson's disease	Control
Pneumonia	84 (53.2%)	6 (17.6%)
Cardiac	33 (20.9%)	9 (26.5%)
Cancer	10 (6.3%)	8 (23.5%)
Cerebrovascular	12 (7.6%)	4 (11.8%)
Parkinson's disease	7 (4.4%)	0
Other*	12	7

* Other includes, Sepsis; Dementia; Immobility; Chronic obstructive pulmonary disease; Old age; Fracture neck of Femur; Multi-organ failure; Motor Neurone disease.

1
2
3 **Funding:** This research received no specific grant from any funding
4 agency in the public, commercial or not-for-profit sectors.
5

6 **Contributors:** PH and RJM conceived and designed the study,
7 collected the data, and managed the database. PH managed the
8 database, contributed to data cleaning, performed the statistical
9 analyses. PH and RJM contributed to interpretation of the data. PH
10 and RJM wrote the manuscript. All authors critically reviewed the
11 manuscript and approved the final version to be published.
12

13 **Competing interests:** None declared.
14

15 **Patient consent:** All participants gave their informed and written
16 consent on participation.
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18 **Data sharing statement:** No additional data available.
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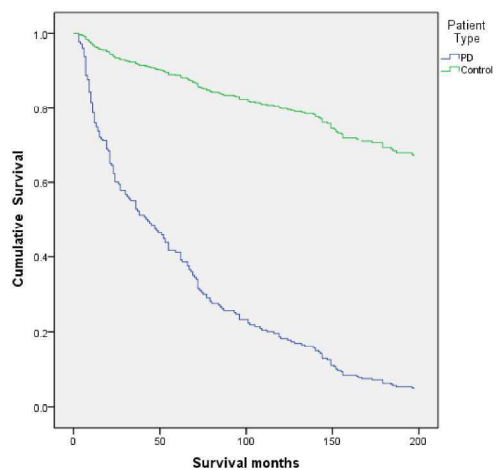


Figure 1.
Kaplan-Meier survival curves for all cause mortality in the PD and control cohorts

297x420mm (300 x 300 DPI)

STROBE 2007 (v4) checklist of items to be included in reports of observational studies in epidemiology*
Checklist for cohort, case-control, and cross-sectional studies (combined)

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(a) Indicate the study’s design with a commonly used term in the title or the abstract	1
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3
Objectives	3	State specific objectives, including any pre-specified hypotheses	3,4
Methods			
Study design	4	Present key elements of study design early in the paper	4
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	4
Participants	6	(a) <i>Cohort study</i> —Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up <i>Case-control study</i> —Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls <i>Cross-sectional study</i> —Give the eligibility criteria, and the sources and methods of selection of participants	4
		(b) <i>Cohort study</i> —For matched studies, give matching criteria and number of exposed and unexposed <i>Case-control study</i> —For matched studies, give matching criteria and the number of controls per case	4
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	4
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	4,5
Bias	9	Describe any efforts to address potential sources of bias	5,6,8
Study size	10	Explain how the study size was arrived at	n/a
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	n/a
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	5
		(b) Describe any methods used to examine subgroups and interactions	5
		(c) Explain how missing data were addressed	n/a
		(d) <i>Cohort study</i> —If applicable, explain how loss to follow-up was addressed <i>Case-control study</i> —If applicable, explain how matching of cases and controls was addressed	n/a

		<i>Cross-sectional study</i> —If applicable, describe analytical methods taking account of sampling strategy	
		(e) Describe any sensitivity analyses	n/a
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	5
		(b) Give reasons for non-participation at each stage	n/a
		(c) Consider use of a flow diagram	--
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	5
		(b) Indicate number of participants with missing data for each variable of interest	n/a
		(c) <i>Cohort study</i> —Summarise follow-up time (eg, average and total amount)	5,6
Outcome data	15*	<i>Cohort study</i> —Report numbers of outcome events or summary measures over time	5,6
		<i>Case-control study</i> —Report numbers in each exposure category, or summary measures of exposure	5,6
		<i>Cross-sectional study</i> —Report numbers of outcome events or summary measures	--
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	5,6
		(b) Report category boundaries when continuous variables were categorized	5,6
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	5,6
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	5,6
Discussion			
Key results	18	Summarise key results with reference to study objectives	6
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	8
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	8
Generalisability	21	Discuss the generalisability (external validity) of the study results	6-8
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	9

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at www.strobe-statement.org.