

Survival and life-expectancy in a young-onset dementia cohort with six years of follow-up: the NeedYD-study

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ABSTRACT

Objectives: The aim of this study was to investigate survival time and life-expectancy in people with young-onset dementia (YOD) and to examine the relationship with age, sex, dementia subtype and comorbidity.

Design, Setting and Participants: Survival was examined in 198 participants in the Needs in Young-onset Dementia study, including participants with Alzheimer's dementia (AD), vascular dementia (VaD) and frontotemporal dementia (FTD).

Measures: The primary outcomes were survival time after symptom onset and after date of diagnosis. Cox proportional hazards models were used to explore the relationship between survival and age, sex, dementia subtype and comorbidity. Additionally, the impact on remaining life expectancy was explored.

Results: During the six-year follow-up, 77 of the participants died (38.9%), 78 participants survived (39.4%) and 43 were lost to follow-up (21.7%). The mean survival time after symptom onset and diagnosis was 209 months (95% CI 185–233) and 120 months (95% CI 110–130) respectively. Participants with AD had a statistically significant shorter survival compared with VaD participants, both regarding survival after symptom onset ($p = 0.047$) as well as regarding survival after diagnosis ($p = 0.049$). Younger age at symptom onset or at diagnosis was associated with longer survival times. The remaining life expectancy, after diagnosis, was reduced with 51% for males and 59% for females compared to the life expectancy of the general population in the same age groups.

Conclusion/Implications: It is important to consider the dementia subtype when persons with YOD and their families are informed about the prognosis of survival. Our study suggests longer survival times compared to other studies on YOD, and survival is prolonged compared to studies on LOD. Younger age at symptom onset or at diagnosis was positively related to survival but diagnosis at younger ages, nevertheless, still diminishes life expectancy dramatically.

Key words: Young Onset Dementia, Dementia, Long-Term Care

Introduction

Between 2% and 10% of the approximately 9.9 million persons who are annually diagnosed with

dementia worldwide, experience their first symptoms before the age of 65 years; this is, so-called young-onset dementia (YOD) (Carter *et al.*, 2018; Prince, *et al.*, 2016; World-Health-Organization, 2012). Better insight into survival time and associated characteristics is necessary to improve our understanding of young-onset neurodegenerative diseases, and for planning specific services. Knowledge can be increased by gaining more insight into the differences in survival regarding the different

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causes of YOD, in particular for the three most common dementia subtypes in YOD. Furthermore, besides age and gender, also the potential influence of comorbidity should not be underestimated even in younger individuals, but this has not been considered in earlier studies on YOD.

There is no consensus in literature that YOD has a more progressive disease course resulting in shorter survival compared to late-onset dementia (LOD) (onset > 65 years) (Barclay *et al.*, 1985b; Diehl-Schmid *et al.*, 2007; Gerritsen *et al.*, 2018; Gronning *et al.*, 2012; Jacobs *et al.*, 1994; Koedam *et al.*, 2008; Panegyres and Chen, 2013; Stanley and Walker, 2014; van der Vlies *et al.*, 2009). Younger age has been found to be negatively associated with survival in Alzheimer's dementia (AD) and frontotemporal dementia (FTD) studies (Barclay *et al.*, 1985a; Diehl-Schmid *et al.*, 2007). However, despite the higher mortality risk in YOD found by Koedam *et al.* (2008), survival of YOD participants was longer compared with LOD (Koedam *et al.*, 2008). Furthermore, male sex in YOD is not consistently associated with shorter survival, while comorbidity shows a more consistent negative relationship with survival in YOD (Armstrong, 2014; Barclay *et al.*, 1985b; Brodaty *et al.*, 2012; Kay *et al.*, 2000). In the review of Brodaty *et al.* (2012), men and women showed the same life expectancy, but in this comparison no distinction was made between those with YOD and LOD (Brodaty *et al.*, 2012).

Knowing the characteristics that are related to survival in YOD can help in providing a prognosis, and in reducing feelings of uncertainty after diagnosis (Stokes *et al.*, 2015). The aim of this longitudinal cohort study was to investigate the survival time of people with YOD from both disease onset and date of diagnosis and the association of YOD with age at onset or diagnosis, gender, dementia subtype and comorbidity. Furthermore, we investigated the impact of the diagnosis of YOD on life expectancy.

Methods

Study design and selection of participants

Participants were selected from the Needs in Young-onset Dementia (NeedYD) study, which has been described previously (van Vliet *et al.*, 2010). Participants were recruited from university medical centres, regional hospitals, mental health services and specialized Dutch day-care facilities. Only participants with AD, Vascular dementia (VaD)/mixed dementia and FTD were included in this study. Dementia subtypes were established according to regular criteria and the consensus on clinical dementia subtypes (Erkinjuntti, 1994; McKhann *et al.*, 1984; Neary *et al.*, 1998). The study protocol

was approved by the Medical Ethics Committee of the University Medical Center, Maastricht. The local ethics committees of the participating institutions also gave consent. The research study was performed according to the principles of the Declaration of Helsinki (version January 2004; www.wma.net) and is in agreement with the law regarding medical-scientific research in humans (WMO). Data collection, after written informed consent was obtained, started in 2007 and 2008 (baseline). Information about the study was provided by the memory clinics or day-care facilities, and then again by the researcher. Participants who were not able to sign informed consent were asked to give oral consent and also their legal representative was asked to give written consent. This was followed by assessments at six-month intervals for two years and then at three, four and six years after inclusion.

Primary outcomes

Survival from symptom onset and *survival from date of diagnosis* were calculated in months. Using a semi-structured open-ended interview, the primary caregivers were asked for the date of the earliest signs or symptoms. Then, they were asked to elaborate on their answers and identify if there were any earlier signs or symptoms. The date of the earliest signs or symptoms, cognitive, behavioural or functional, was recorded as the date of symptom onset. Date of dementia was retrieved from the participants' medical records. The date of symptom onset was set at January first in the year of onset if the exact date was not known by the primary caregiver. For both outcomes, survival time was calculated from date of symptom onset or date of diagnosis to date of death or date of censoring (date of the last contact with the participant or caregiver is used in the analysis, at that time participant is still alive) during the six-year follow up.

Determinants

Dementia subtype was established according to the criteria of McKhann, the NINDS-AIREN criteria, the consensus on clinical diagnostic criteria of FTD and the consensus on clinical dementia subtypes (Erkinjuntti, 1994; First *et al.*, 2002; McKhann *et al.*, 1984; Neary *et al.*, 1998). *Age at symptom onset* and *age at diagnosis* were calculated in years from date of birth and date at symptom onset or date at diagnosis, respectively. *Comorbidity* was registered at baseline using the participants' medical records and structured interviews with the primary caregiver. *Comorbidity* was classified by the first author (AG), using the International Classification of Diseases, 10th Revision (ICD-10) (World Health Organization). The ICD-10 classifies diseases in

Table 1. Baseline findings

	ALL (N = 198)	AD (N = 122)	VaD (N = 34)	FTD (N = 42)	TEST*
Male (%)	105 (53.0)	57 (46.7)	22 (64.7)	26 (61.9)	χ^2 (df 2) = 5.318, p = 0.08
Mean age at inclusion (SD) [range]	61.4 (5.5) [43.4–74.7]	61.5 (4.9) [48.6–73.5]	61.2 (5.3) [46.4–69.6]	61.4.4 (7.3) [43.4–74.7]	F(2,198) = 0.38, p = 0.96
Mean age at diagnosis (SD) [N]	58.7 (5.5) [197]	58.9 (5.0) [122]	58.1 (5.2) [34]	58.5 (7.2) [41]	F(2,196) = 0.241, p = 0.79
Mean age at symptom onset (SD) [N]	54.3 (6.5) [197]	54.5 (5.5) [121]	53.2 (6.7) [34]	54.7 (8.6) [42]	F(2,196) = 0.594, p = 0.55
Time in months between symptom onset and diagnosis (SD) [N]	53 (44) [196]	52 (45) [121]	59 (46) [34]	49 (39) [41]	F(2,195) = 0.491, p = 0.61
Mean GDS (SD) [N]	4.4 (1.1) [188]	4.7 (1.0) [118]	3.9 (1.0) [31]	4.1 (1.3) [39]	χ^2 (df 10) = 30.189, p = 0.001**
Comorbidity N (%)	95 (48.0)	53 (43.4)	18 (52.9)	24 (57.1)	χ^2 (df 2) = 2.754, p = 0.25

AD: Alzheimer's dementia, VaD: vascular dementia including mixed AD/VaD, FTD: frontotemporal dementia.

*Comparison among diagnosis groups, χ^2 or F-test (ANOVA),

**Significant difference among AD and VaD, FTD.

categories, with sub-categories to describe specific diseases. For the current study, classification was performed at the sub-category level, or, if the information was not specific enough, at the category level.

Demographic characteristics

Sex, *date of birth*, and *date of death* were collected through structured interviews with primary caregivers. *Dementia severity* at baseline was assessed using the Global Deterioration Scale (GDS), which rates dementia severity from “no impairment” (GDS stage 1) to “very severe cognitive impairment” (GDS stage 7) (Reisberg *et al.*, 1982).

Statistical analysis

The analyses were performed using the Statistical Package for Social Sciences (SPSS), version 22.2.0.01 (2013), (IBM SPSS Statistics, IBM Corporation, Chicago, IL). Proportions and means were calculated to describe characteristics of the participants. Group comparisons regarding dementia subtypes (AD, VaD, FTD) were analysed using analysis of variance (ANOVA) for continuous variables or chi-squared tests and log-rank tests for categorical variables. Survival analyses were performed with the Kaplan-Meijer estimator (Kaplan and Meier, 1958). Cox proportional hazards (CPH) models were used to relate age at symptom onset or age at diagnosis, sex, dementia subtype and comorbidity with survival (Breslow, 1974; Crowley and Breslow, 1984). A sub-analysis on age at symptom onset or diagnosis was performed to see if there were differences between the diagnoses. Comorbidity was classified “yes” when one

or more comorbid conditions were present; otherwise, classification was “no.” A t-test was used in a sensitivity analysis whether or not to consider left truncation. Left truncation means that a correction may be needed for potential participants who did not survive until the date of inclusion, and, thus, did not enter the study population, resulting in possible overestimation of survival (Addona *et al.*, 2012; Vansteelandt *et al.*, 2017). For this sensitivity analysis, the study population was divided into two groups, one with the participants who had the longest baseline survival time from symptom onset and one with the shortest. The two groups were compared considering the survival time during the six-year follow-up. A similar sensitivity analysis was performed for the groups with the longest and shortest baseline survival times from date of diagnosis. The relative loss of remaining life expectancy was calculated in percentages by dividing the years of life lost after diagnosis by the matched life expectancy in the Dutch general population aged 61 in 2007 (Statline, 2017a).

For all analyses, a P-value <0.05 was used as the threshold for statistical significance.

Results

A total of 198 participants were included, 122 with AD, 34 with VaD/mixed dementia, and 42 with FTD (van Vliet *et al.*, 2010). The mean age at diagnosis was 58.6 (SD 5.5) years and median time from diagnosis until inclusion was 2.2 years (IQR 0.9–4.0). There were slightly more male than female participants (Table 1).

Table 2. Survival in months

	ALL (N = 198)	AD (N = 122)*	VaD (N = 34)	FTD (N = 42)*	TEST**
After diagnosis					
mean (SD)	120 (5.0)	111 (5.8)	142 (11.7)	120 (9.9)	χ^2 (df 2) = 8.064, p = 0.018
[95% CI]	[110–130]	[100–123]	[119–165]	[101–140]	
median [95%CI]	112 [101–123]	103 [88–119]	179***	135 [111–158]	
After symptom onset					
mean (SD)	209 (12.1)	187 (13.2)	270 (29.5)	197 (12.6)	χ^2 (df 2) = 7.511, p = 0.023
[95% CI]	[185–233]	[161–213]	[212–327]	[172–221]	
median [95%CI]	194 [139–249]	156 [128–184]	***	245***	

AD: Alzheimer's dementia, VaD: vascular dementia including mixed dementia, FTD: frontotemporal dementia. * One missing value on FTD date of diagnosis, one missing value on AD date of symptom onset.

**Comparison among diagnosis groups,

***Too many survivors to calculate 95%CI,

****Too many survivors to calculate median.

Table 3. Cox proportional hazard ratios

	SURVIVAL AFTER SYMPTOM ONSET						95.0% CI FOR	
	B	SE	WALD	DF	SIG.	EXP(B)	EXP(B)	
							LOWER	UPPER
Dementia subtype			6.271	2	.043			
Alzheimer's dementia	.771	.387	3.960	1	0.047	2.162	1.012	4.618
Frontotemporal dementia	.141	.466	.092	1	.762	1.152	.462	2.871
Vascular dementia* (ref)								
Gender	-.060	.241	.063	1	.80	.941	.587	1.511
Comorbidity (yes/no)	.281	.231	1.470	1	.23	1.324	.841	2.084
Age at symptom onset	.133	.023	32.641	1	<.001	1.142	1.091	1.196
Alzheimer's dementia	.137	.029	22.284	1	<.001	1.147	1.084	1.215
Vascular dementia*	.164	.079	4.284	1	.04	1.178	1.009	1.375
Frontotemporal dementia	.149	.057	6.795	1	.009	1.161	1.038	1.298

*Vascular dementia including vascular/mixed Alzheimer's dementia (-2 log likelihood 654.884), p < .0001.

Survival

During the six-year follow-up, 77 of the participants died (38.9%), 78 participants survived (39.4%) and 43 were lost to follow-up (21.7%). Kaplan-Meijer analysis showed a mean survival time from symptom onset of 209 months (95% CI 185–233) and a mean survival time after diagnosis of 120 months (95% CI 110–130) (Table 2). This corresponds with 17 years and 5 months and 10 years, respectively. In 2007, at the time of the first assessment in our study, general life expectancy in healthy adults at age 60 in the Netherlands was 21.4 years in males and 25.2 years in females (Statline, 2017a). The expected loss of life years found in this study is approximately 11 years for male participants and approximately 15 years for female participants. The relative loss of remaining life expectancy after diagnosis was 52% in male participants and 61% in female participants, compared to the life expectancy of the general population in the same age groups.

Determinants of survival

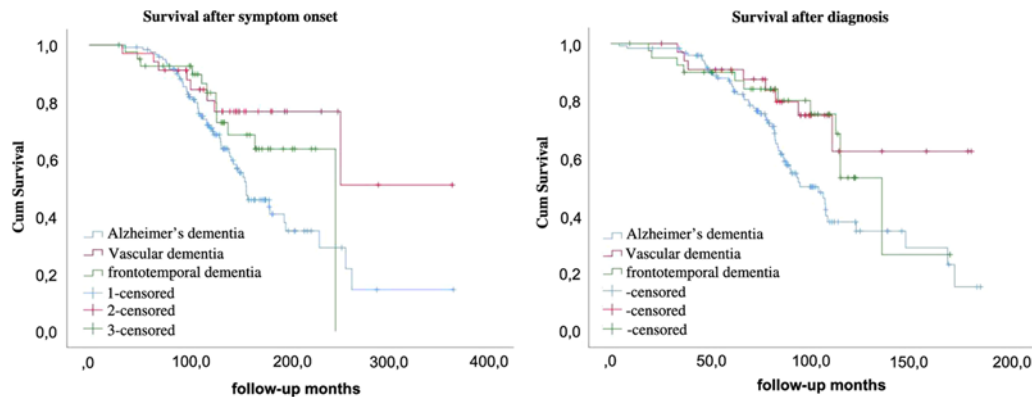
A diagnosis of AD decreased the likelihood of survival by 2.16 times compared with a VaD diagnosis (Table 3, Figure 1). We also found a trend of a decreased survival for the participants with AD compared with FTD participants. The same association between dementia subtypes and survival from the date of diagnosis was found (Table 4, Figure 1).

Age at symptom onset also showed an association with survival. The likelihood of a shorter survival increased 14% with each additional year of age at symptom onset (Table 3). This likelihood of a shorter survival was found in all three dementia subtypes (Table 3). In the CPH model of survival from date of diagnosis, a similar relationship between age at diagnosis and survival was found, with an almost 7% higher chance of a shorter survival with each extra year of age at the time of diagnosis (Table 4). In the sub analysis, however, statistical significance only was seen for AD and FTD subtypes.

Table 4. Cox proportional hazard ratios

	SURVIVAL AFTER DIAGNOSIS						
	B	SE	WALD	DF	SIG.	EXP(B)	95.0% CI FOR EXP(B)
							LOWER UPPER
Dementia subtype			6.091	2	.048		
Alzheimer's dementia	.761	.386	3.887	1	.049	2.140	1.004 4.559
Frontotemporal dementia	.161	.463	.122	1	.727	1.175	.475 2.909
Vascular dementia* (ref)							
Gender	.020	.237	.007	1	.93	1.021	.642 1.623
Comorbidity (yes/no)	.126	.245	.264	1	.61	1.134	.702 1.831
Age at symptom onset	.067	.021	9.940	1	.002	1.069	1.026 1.115
Alzheimer's dementia	.082	.034	5.943	1	.015	1.085	1.016 1.154
Vascular dementia*	.071	.082	.0762	1	.38	1.074	.915 1.261
Frontotemporal dementia	.156	.058	7.347	1	.007	1.169	1.044 1.308

* Vascular dementia including vascular/mixed Alzheimer's dementia (-2 Log Likelihood 677.183), $p = 0.004$.

**Figure 1.** Survival.

No association was found between survival and sex, or having comorbid conditions in either CPH models.

The sensitivity analysis concerning left truncation revealed no significant difference in survival time during the six-year follow up. The mean difference was 0.4 months between the group with the longest versus shortest baseline survival time of diagnosis ($p = 0.884$). For symptom onset, the mean difference was 0.1 months in the six-year follow up ($p = 0.965$).

Discussion

The survival from date of diagnosis found in our study was substantially less than the general life expectancy in the Netherlands (Statline, 2017a). Furthermore, survival times after symptom onset and after diagnosis were associated with dementia subtypes but not with comorbidity or with sex.

The relative loss of more than 50% of remaining life expectancy that we found is lower than in a review by Brodaty *et al.* (2012) who calculated percentages of 60–94% in YOD populations (Brodaty *et al.*, 2012). This lower loss of remaining life expectancy is in line with the longer survival times we found, but the outcome for these young persons with dementia is dramatic. Furthermore, in that review more dementia subtypes were included compared to our study, among which FTD with motor neuron disease, which also can contribute to the differences we found on the relative loss of remaining life expectancy.

The survival time after symptom onset found in our study was prolonged by about five years compared with findings in other studies (Brodaty *et al.*, 2012; Todd *et al.*, 2013). However, none of the study populations included in those reviews are comparable with our population. Todd *et al.* (2013) investigated survival after symptom onset in a review of

studies in dementia, in general, not specifically in YOD (Todd *et al.*, 2013). In a review by Brodaty *et al.* (2012), ten studies reported on survival in YOD, of which five on YOD specifically, and two of them reported on survival after symptom onset (Jost and Grossberg, 1995; McGonigal *et al.*, 1992). Median survival times from symptom onset reported in those two studies ranged from 5.8–10.8 years, while in our study this was 9.3 years. The study populations in those two studies are from before 1995; after this time, survival in the general population, and likely also in persons with YOD, has increased because of less mortality due to cardiovascular disease and cancer (Milieu, 2018). Furthermore, we thoroughly investigated the date of first symptoms.

Mean survival after diagnosis in our study is approximately two years longer than the longest survival time (7.9 years) reported in a review of Brodaty *et al.* (2012) (Brodaty *et al.*, 2012). In two studies investigating survival after diagnosis, median survival times ranged from approximately 3.4 to 6 years in young participants. The study populations of those two studies differed from our population. One study included AD and VaD, while we also included FTD. The other study examined survival times regardless of dementia subtype (Kay *et al.*, 2000; Koedam *et al.*, 2008). We know that the time needed to establish a diagnosis of YOD, and accuracy has been improved during the 20 years between the start of the study of Kay *et al.* (2000) and the start of our study, due to improved structural behavioural and psychiatric assessments, neuroimaging and the examination of cerebrospinal fluid (Kay *et al.*, 2000; Rossor *et al.*, 2010). This likely resulted in an earlier diagnosis in our cohort and, consequentially, a longer survival after diagnosis.

We found an association of dementia subtypes with survival in which AD participants had lower survival rates compared to VaD participants. This seems in contrast with the results of other studies that found an equal or longer survival in AD subtypes compared with VaD (Kay *et al.*, 2000; Koedam *et al.*, 2008). However, again, these figures are from populations that show some important differences from our study population. Kay *et al.* (2000) only compared AD and VaD, and Koedam *et al.* (2008) made a comparison of all the study participants (young and elderly) with a control group of participants without dementia (Kay *et al.*, 2000; Koedam *et al.*, 2008).

Having a diagnosis or symptoms of dementia at a younger age resulted in this study in higher survival rates, which has also been found by others, who found longer survival times in younger YOD persons (Jost and Grossberg, 1995; Knopman *et al.*, 2003). Within a young-onset Alzheimer's dementia (YO-AD) study population, the opposite was found;

younger AD participants showed higher mortality rates in comparison with those who were older at the time of diagnosis, and some studies found no association of age with survival (Kay *et al.*, 2000; McGonigal *et al.*, 1992; Ueki *et al.*, 2001). We found no YOD studies investigating the association of age with survival, in which, survival analysis were performed correcting for dementia subtypes (Hodges *et al.*, 2003; Knopman *et al.*, 2003; Rait *et al.*, 2010; Roberson *et al.*, 2005). It is known that in LO-AD, younger age is related to shorter survival. We found the opposite for all dementia subtypes. We do know that comorbidity in YO-AD is less compared to LO-AD; however, we included comorbidity in the statistical model to correct for this factor. We found the opposite for all dementia subtypes. We do know that comorbidity in YO-AD is less compared to LO-AD, but we corrected for comorbidity when we found this outcome (Gerritsen *et al.*, 2016; Hodges *et al.*, 2003; Holland *et al.*, 2012; Knopman *et al.*, 2003; Perrault *et al.*, 2002; Rait *et al.*, 2010; Rasmusson *et al.*, 1996; Roberson *et al.*, 2005; Stanley and Walker, 2014). Therefore, the finding that the youngest participants showed the longest survival, might be due to their better physical condition in comparison to the older YOD participants.

For age at symptom onset, all three dementia subtypes showed an association with longer survival when symptoms arose earlier, but for age at diagnosis, the subanalysis showed no statistical significance for the VaD participants (Tables 3 and 4).

No association has been found between survival and the presence (or lack) of comorbidity. We found only one study on YO-AD investigating this association between comorbidity and survival (Ueki *et al.*, 2001). In that study, concurrent physical illness was found to negatively influence survival, but our analysis did not show this outcome. The findings of our study might suggest that persons with YOD have a disease trajectory that is less affected by comorbidity compared with LOD, as was also found in a study on YO-AD (Chang *et al.*, 2017). Furthermore, it is likely that frailty, including the burden of comorbidity, might be a more important risk factor of mortality in LOD than comorbidity (Kane *et al.*, 2012).

Sex showed no association with survival in our study, and it remains unclear why this finding differs from many LOD studies in which male sex has been found to be associated with shorter survival (Garcia-Ptacek *et al.*, 2014; Ientile *et al.*, 2013; Lee and Chodosh, 2009). However, in the review of Brodaty *et al.* (2012) men and women showed the same life expectancy taking no account for the categories YOD and LOD (Brodaty *et al.*, 2012). The a priori chance of dying before 2016, when aged 61 in 2007, in the Netherlands was less than 2% in males and

less than 1.5% in females. Therefore, dementia, and not sex, is more likely the main cause of the limited survival at this age (Statline, 2017b).

Limitations and strengths

There are some limitations in this study that have to be considered. First, by setting January first as the date of symptom onset when the exact date was not available, survival could be prolonged six months, on average. However, knowing that there were 77 survivors means that survival time will be longer when we would have been able to extend our follow-up period beyond six years. Of course, it is difficult for caregivers to give an exact date of symptom onset, because dementia often has an insidious onset. This can result in a possible under- or overestimation of survival time after symptom onset. However, this is inherent to the study design. Second, we were not able to include disease severity at diagnosis in the CPH models because this information was not available. There are some indications that disease severity at diagnosis shows a relationship with survival; however, not all studies found this relationship (Atkins *et al.*, 2012; Ientile *et al.*, 2013; Todd *et al.*, 2013; Tschanz *et al.*, 2004). Third, 21.7% of the participants were lost during our six-year follow-up and 39.4% survived. We think losing participants is inherent for long lasting cohort studies. The chosen statistical analysis, Kaplan-Meijer, can address this loss and surviving participants; however, outcomes remain estimates until all participants are deceased. Fourth, unfortunately, we had no access to the death certificates to examine the causes of death. This would be helpful as in a study on survival, information about causes of death is informative for both families and clinicians. However, our study did reveal survival times for the three most common subtypes of dementia in YOD and showed that comorbidity was not related to survival. Fifth, we did not have information on the severity of the comorbid conditions, which would have been interesting to take into account. Also, we had no information on intercurrent diseases such as pneumonia which could have influenced survival. However, studying the relationship of comorbidity and survival in YOD, is a reasonably unexplored topic.

The strength of our study is the sensitivity analysis we did on left truncation. Cohort studies are frequently influenced because some potential participants do not enter the study because they pass away before the date of inclusion, which is considered left truncation (Addona *et al.*, 2012; Vansteelandt *et al.*, 2017). However, we found that survival time after the date of diagnosis in our cohort was not influenced due to this effect, and this was confirmed with the sensitivity analysis.

Conclusion/Relevance

Our study outcomes add information to the knowledge about survival in YOD and provide support for longer survival in persons with YOD compared to LOD. This underlines the need for long lasting support systems that are focused on the needs of these patients.

An indication was found for a different survival in the three main subtypes of YOD, with AD participants having the shortest survival. Therefore, an accurate diagnosis is relevant to take into account concerning prognosis.

Distress and uncertainty perhaps can be diminished by using our study outcomes when informing individuals with YOD and their families. Nevertheless, lost life years, both absolute and relative, will have an impact on the future perspective of these persons and their families. This burden is added to the uncertainty about prognosis and life expectancy, after the struggle of getting a proper diagnosis (Baptista *et al.*, 2016; van Vliet *et al.*, 2011). Our findings are perhaps not as negative as often thought, but they address the reason for intensive care support as long as dementia is only treatable symptomatically.

A recommendation for future research might be to include disease severity at the time of diagnosis in studies on survival in patients with YOD. Death certificates or interviews with caregivers can help to better clarify our understanding of the relationship between an early death and the course of the dementia. Furthermore, given the different findings about survival in young persons with FTD, survival in this dementia subgroup also needs further investigation.

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Conflicts of interest

None.

Description of authors' roles

A. Gerritsen designed the study, collected parts of the data, performed the analyses and wrote the paper. C. Bakker designed the study, collected parts of the data and co-wrote the paper. J. Millenaar

collected parts of the data and critically reviewed the paper. R. Koopmans designed the study and critically reviewed the paper. F. Verhey, Y. Pijnenburg and M. de Vugt advised about the study design and critically reviewed the paper.

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References

- Addona, V., Atherton, J. and Wolfson, D. B. (2012). Testing the assumptions for the analysis of survival data arising from a prevalent cohort study with follow-up. *The International Journal of Biostatistics* 8, 22.
- Armstrong, R. A. (2014). Factors determining disease duration in Alzheimer's disease: a postmortem study of 103 cases using the Kaplan-Meier estimator and Cox regression. *BioMed Research International*, 2014, 623487.
- Atkins, E. R., Bulsara, M. K. and Panegyres, P. K. (2012). The natural history of early-onset dementia: the Artemis Project. *BMJ Open*, 2, e001764.
- Baptista, M. A. *et al.* (2016). Quality of life in young onset dementia: an updated systematic review. *Trends Psychiatry Psychother*, 38, 6–13.
- Barclay, L. L., Zemcov, A., Blass, J. P. and McDowell, F. H. (1985a). Factors associated with duration of survival in Alzheimer's disease. *Biological Psychiatry*, 20, 86–93.
- Barclay, L. L., Zemcov, A., Blass, J. P. and Sansone, J. (1985b). Survival in Alzheimer's disease and vascular dementias. *Neurology*, 35, 834–840.
- Breslow, N. (1974). Covariance analysis of censored survival data. *Biometrics*, 30, 89–99.
- Brodaty, H., Seeher, K. and Gibson, L. (2012). Dementia time to death: a systematic literature review on survival time and years of life lost in people with dementia. *International Psychogeriatrics*, 24, 1034–1045.
- Carter, J. E., Oyebode, J. R. and Koopmans, R. (2018). Young-onset dementia and the need for specialist care: a national and international perspective. *Aging and Mental Health*, 22, 468–473.
- Chang, K. J. *et al.* (2017). Mortality risk after diagnosis of early-onset Alzheimer's disease versus late-onset Alzheimer's disease: a propensity score matching analysis. *Journal of Alzheimer's Disease*, 56, 1341–1348.
- Crowley, J. and Breslow, N. (1984). Statistical analysis of survival data. *Annual Review of Public Health*, 5, 385–411.
- Diehl-Schmid, J., Pohl, C., Perneczky, R., Hartmann, J., Forstl, H. and Kurz, A. (2007). [Initial symptoms, survival and causes of death in 115 patients with frontotemporal lobar degeneration]. *Fortschritte der Neurologie-Psychiatrie*, 75, 708–713.
- Erkinjuntti, T. (1994). Clinical criteria for vascular dementia: the NINDS-AIREN criteria. *Dementia*, 5, 189–192.
- First, M. B., Frances, A. and Pincus, H. A. (2002). *DSM-IV-TR, handbook of differential diagnosis*. Arlington, VA: American Psychiatric Publishing, Inc.
- Garcia-Ptacek, S., Farahmand, B., Kareholt, I., Religa, D., Cuadrado, M. L. and Eriksdotter, M. (2014). Mortality risk after dementia diagnosis by dementia type and underlying factors: a cohort of 15, 209 patients based on the Swedish Dementia Registry. *Journal of Alzheimer's Disease*, 41, 467–477.
- Gerritsen, A. A. *et al.* (2016). Prevalence of comorbidity in patients with young-onset Alzheimer disease compared with late-onset: a comparative cohort study. *Journal of the American Medical Directors Association*, 17, 318–323.
- Gerritsen, A. A. J. *et al.* (2018). The progression of dementia and cognitive decline in a Dutch 2-Year cohort study of people with young-onset dementia. *Journal of Alzheimer's Disease*, 63, 343–351.
- Gronning, H., Rahmani, A., Gyllenberg, J., Dessau, R. B. and Høgh, P. (2012). Does Alzheimer's disease with early onset progress faster than with late onset? A case-control study of clinical progression and cerebrospinal fluid biomarkers. *Dementia and Geriatric Cognitive Disorders*, 33, 111–117.
- Hodges, J. R., Davies, R., Xuereb, J., Kril, J. and Halliday, G. (2003). Survival in frontotemporal dementia. *Neurology*, 61, 349–354.
- Holland, D., Desikan, R. S., Dale, A. M., McEvoy, L. K. and Alzheimer's Disease Neuroimaging, I. (2012). Rates of decline in Alzheimer disease decrease with age. *PLoS One*, 7, e42325.
- Ientile, L. *et al.* (2013). Survival rate in patients affected by dementia followed by memory clinics (UVA) in Italy. *Journal of Alzheimer's Disease*, 36, 303–309.
- Jacobs, D. *et al.* (1994). Age at onset of Alzheimer's disease: relation to pattern of cognitive dysfunction and rate of decline. *Neurology*, 44, 1215–1220.
- Jost, B. C. and Grossberg, G. T. (1995). The natural history of Alzheimer's disease: a brain bank study. *Journal of the American Geriatrics Society*, 43, 1248–1255.
- Kane, R. L., Shamlivan, T., Talley, K. and Pacala, J. (2012). The association between geriatric syndromes and survival. *Journal of the American Geriatrics Society*, 60, 896–904.
- Kaplan, E. L. and Meier, P. (1958). Nonparametric-estimation from incomplete observations. *Journal of the American Statistical Association*, 53, 457–481.
- Kay, D. W., Forster, D. P. and Newens, A. J. (2000). Long-term survival, place of death, and death certification in clinically diagnosed pre-senile dementia in northern England. Follow-up after 8–12 years. *British Journal of Psychiatry*, 177, 156–162.
- Knopman, D. S., Rocca, W. A., Cha, R. H., Edland, S. D. and Kokmen, E. (2003). Survival study of vascular dementia in Rochester, Minnesota. *Archives of Neurology*, 60, 85–90.
- Koedam, E. L. *et al.* (2008). Early-onset dementia is associated with higher mortality. *Dementia and Geriatric Cognitive Disorders*, 26, 147–152.
- Lee, M. and Chodosh, J. (2009). Dementia and life expectancy: what do we know? *Journal of the American Medical Directors Association*, 10, 466–471.
- McGonigal, G., McQuade, C. A., Thomas, B. M. and Whalley, L. J. (1992). Survival in presenile Alzheimer's and multi-infarct dementias. *Neuroepidemiology*, 11, 121–126.

- McKhann, G., Drachman, D., Folstein, M., Katzman, R., Price, D. and Stadlan, E. M.** (1984). Clinical diagnosis of Alzheimer's disease: report of the NINCDS-ADRDA Work Group under the auspices of Department of Health and Human Services Task Force on Alzheimer's Disease. *Neurology*, 34, 939–944.
- Milieu, R.** (2018). Volksgezondheid Toekomst Verkenning 2018: Een gezond vooruitzicht. (Rijksinstituut voor Volksgezondheid en Milieu. Dutch National Institute for Public Health and the Environment.) Bilthoven. Available at: <https://www.rivm.nl/bibliotheek/rapporten/2018-0030.pdf>; last accessed August 2018.
- Neary, D. et al.** (1998). Frontotemporal lobar degeneration: a consensus on clinical diagnostic criteria. *Neurology*, 51, 1546–1554.
- Panegyres, P. K. and Chen, H. Y.** (2013). Differences between early and late onset Alzheimer's disease. *American Journal of Neurodegenerative Disease*, 2, 300–306.
- Perrault, A., Wolfson, C., Egan, M., Rockwood, K. and Hogan, D. B.** (2002). Prognostic factors for functional independence in older adults with mild dementia: results from the Canadian study of health and aging. *Alzheimer Disease and Associated Disorders*, 16, 239–247.
- Prince, M., Wimo, A., Guerchet, M., Ali, G.C., Wu, Y.T., Prina, M.** (2016). *World Alzheimer Report 2016*. London: Alzheimer's Disease International.
- Rait, G., Walters, K., Bottomley, C., Petersen, I., Iliffe, S. and Nazareth, I.** (2010). Survival of people with clinical diagnosis of dementia in primary care: cohort study. *BMJ*, 341, c3584.
- Rasmusson, D. X., Carson, K. A., Brookmeyer, R., Kawas, C. and Brandt, J.** (1996). Predicting rate of cognitive decline in probable Alzheimer's disease. *Brain and Cognition*, 31, 133–147.
- Reisberg, B., Ferris, S. H., de Leon, M. J. and Crook, T.** (1982). The Global Deterioration Scale for assessment of primary degenerative dementia. *The American Journal of Psychiatry*, 139, 1136–1139.
- Roberson, E. D. et al.** (2005). Frontotemporal dementia progresses to death faster than Alzheimer disease. *Neurology*, 65, 719–725.
- Rossor, M. N., Fox, N. C., Mummery, C. J., Schott, J. M. and Warren, J. D.** (2010). The diagnosis of young-onset dementia. *Lancet Neurology*, 9, 793–806.
- Stanley, K. and Walker, Z.** (2014). Do patients with young onset Alzheimer's disease deteriorate faster than those with late onset Alzheimer's disease? A review of the literature. *International Psychogeriatrics*, 26, 1945–1953.
- Statline, Statistics Netherlands' database.** (2017a). Available at <https://opendata.cbs.nl/statline/#/CBS/nl/dataset/37360ned/table?ts=1543837224473>; last accessed 3 December 2018.
- Statline, Statistics Netherlands' database.** (2017b). Sterftekansen naar leeftijd, geslacht. Available at <https://opendata.cbs.nl/statline/#/CBS/nl/dataset/37360ned/table?ts=1543840176015>; last accessed 3 December 2018.
- Stokes, L., Combes, H. and Stokes, G.** (2015). The dementia diagnosis: a literature review of information, understanding, and attributions. *Psychogeriatrics*, 15, 218–225.
- Todd, S., Barr, S., Roberts, M. and Passmore, A. P.** (2013). Survival in dementia and predictors of mortality: a review. *International Journal of Geriatric Psychiatry*, 28, 1109–1124.
- Tschanz, J. T. et al.** (2004). Dementia: the leading predictor of death in a defined elderly population: the Cache County Study. *Neurology*, 62, 1156–1162.
- Ueki, A., Shinjo, H., Shimode, H., Nakajima, T. and Morita, Y.** (2001). Factors associated with mortality in patients with early-onset Alzheimer's disease: a five-year longitudinal study. *International Journal of Geriatric Psychiatry*, 16, 810–815.
- van der Vlies, A. E., Koedam, E. L., Pijnenburg, Y. A., Twisk, J. W., Scheltens, P. and van der Flier, W. M.** (2009). Most rapid cognitive decline in APOE epsilon4 negative Alzheimer's disease with early onset. *Psychological Medicine*, 39, 1907–1911.
- Vansteelandt, S., Dukes, O. and Martinussen, T.** (2017). Survivor bias in Mendelian randomization analysis. *Biostatistics*, 19, 426–443.
- van Vliet, D., Bakker, C., Koopmans, R. T., Vernooij-Dassen, M. J., Verhey, F. R. and de Vugt, M. E.** (2010). Research protocol of the NeedYD-study (Needs in Young onset Dementia): a prospective cohort study on the needs and course of early onset dementia. *BMC Geriatrics*, 10, 13.
- van Vliet, D. et al.** (2011). Caregivers' perspectives on the pre-diagnostic period in early onset dementia: a long and winding road. *International Psychogeriatrics*, 23, 1393–1404.
- World Health Organization** (2012). *Dementia: A Public Health Priority*. Geneva: World Health Organization.
- World Health Organization** (2014). International classification of diseases, 10th revision (ICD-10) online (2014 version). Available at: <https://www.who.int/classifications/icd/icdonlineversions/en>.