Estimating demand for potential disease-modifying therapies for Alzheimer's disease in the UK

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Background

Phase three trials of the monoclonal antibodies lecanemab and donanemab, which target brain amyloid, have reported statistically significant differences in clinical end-points in early Alzheimer's disease. These drugs are already in use in some countries and are going through the regulatory approval process for use in the UK. Concerns have been raised about the ability of healthcare systems, including those in the UK, to deliver these treatments, considering the resources required for their administration and monitoring.

Aims

To estimate the scale of real-world demand for monoclonal antibodies for Alzheimer's disease in the UK.

Method

We used anonymised patient record databases from two National Health Service trusts for the year 2019 to collect clinical, demographic, cognitive and neuroimaging data for these cohorts. Eligibility for treatment was assessed using the inclusion criteria from the clinical trials of donanemab and lecanemab, with consideration given to diagnosis, cognitive performance, cerebrovascular disease and willingness to receive treatment.

Results

We examined the records of 82 386 people referred to services covering around 2.2 million people. After applying the trial criteria, we estimate that a maximum of 906 people per year would start treatment with monoclonal antibodies in the two services, equating to 30 200 people if extrapolated nationally.

Conclusions

Monoclonal antibody treatments for Alzheimer's disease are likely to present a significant challenge for healthcare services to deliver in terms of the neuroimaging and treatment delivery. The data provided here allows health services to understand the potential demand and plan accordingly.

Keywords

Dementias/neurodegenerative diseases; mental health services; pharmaceutical drug trial; out-patient treatment; other imaging.

More than a century since Alzheimer's disease was first described, the first phase 3 clinical trials demonstrating a statistically significant clinical response combined with changes in disease biomarkers have been published.[1,2] These trials used donanemab and lecanemab, which are monoclonal antibodies targeting beta-amyloid, rejuvenating interest in the potential of this approach. After many negative trials of monoclonal antibodies, the contentious re-appraisal of data from two large-scale trials of aducanumab led researchers to believe that optimal design and dosing of anti-amyloid therapies might be associated with a modest clinical benefit.[3] This led to the US Food and Drug Administration's (FDA) 'accelerated approval' for aducanumab in the USA, based largely on clinical extrapolation of reductions in brain amyloid, although the data for clinical outcomes were questionable. This was followed by the publication of a similar phase 2 trial of donanemab (TRAILBLAZER-ALZ[4]) and, subsequently, the phase 3 trials of lecanemab (CLARITY-AD[1]) and donanemab (TRAILBLAZER-ALZ 2[2]), which more definitively reported a slowing of decline in cognitive, functional and other outcomes. The FDA approved lecanemab (marketed in the USA as Leqembi) under the accelerated approval process in January 2023, and gave it full FDA approval in July 2023.[5] Eisai and Biogen have subsequently submitted both a supplemental biologics licence application to the FDA and a marketing authorisation application to the European Medicines Agency.

Potential challenges to delivering treatment

Whether the magnitude of the demonstrated benefit justifies the risks of treatment and economic cost remains contentious.[6,7] One concern has been the ability of healthcare systems, including those in developed nations like the UK, to be able to deliver these treatments in a safe and timely fashion.[8] Anxieties around delivery are tied to the potential volume of the task, given that an ageing population means 96 million people are predicted to be living with dementia worldwide by 2050.[9] The FDA label for lecanemab states that the medication is to treat patients with 'mild cognitive impairment or mild dementia stage of Alzheimer's disease, the population in which treatment was studied in clinical trials'.[5] This implies amyloid positivity would need to be determined either by positron emission tomography (PET) imaging or cerebrospinal fluid (CSF) analysis before treatment. The label also stipulates that a minimum of four magnetic resonance imaging (MRI) brain scans are required to monitor for side-effects; one in the year before initiating treatment and three further scans before the fifth, seventh and 14th infusions. Further scans would be indicated if amyloid-related imaging abnormalities (ARIA) develop, or symptoms suggestive of ARIA. All of these are resource intensive and would require significant investment in new facilities and staff,

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on top of the cost of the drug. Currently, the National Health Service (NHS) in the UK struggles to meet diagnostic demand, with patients facing a 2-year wait in some services.[10] Only 36% of UK psychiatrists believe their service could adapt to start delivering disease-modifying treatments within a year.[8]

Attempts have already begun in the USA to manage access to treatment by restricting lecanemab to patients most likely to benefit, to manage the financial and infrastructural impact and avoid treatment of patients unlikely to benefit. The US Department of Veterans Affairs recently approved funding for lecanemab, but with 'criteria of use'.[11] These imposed several inclusion and exclusion requirements for funding, such as excluding individuals under the age of 65 years and those who are homozygous for apolipoprotein E4 (ApoE4). Others have proposed 'appropriate use recommendations'.[12,13]

Attempts to estimate scale of demand

Estimates have appeared in the general press of more than 100 000 people potentially being eligible for treatment in the UK, although it is not clear how these figures were derived.[14] Others have examined small, specific populations to look at the numbers potentially eligible, but it is not clear how this would translate to a population level.[15] To plan for delivery of these medicines, the best possible informed estimates of potential demand based on large real-world data-sets are urgently needed.

Given this context, we set out to use data from large audits and electronic patient record data sources to predict the potential scale of real-world demand as accurately as possible. We considered established criteria for treatment from clinical trials for which we have informative service-level data. We also consider criteria where we have limited, less precise or no data to guide us, but where we can make a reasonable estimate. Although imperfect, we present what we believe to be the best possible estimate at the current time of the maximal numbers of patients who might require treatment in the UK.

Method

We used the anonymised research patient record database from Cambridgeshire and Peterborough NHS Foundation Trust (CPFT) for the calendar year 2019. This database has overarching ethical approval from the Cambridge Central Research Ethics Committee (approval numbers 12/EE/0407 and 17/EE/0442) and this project was further assessed and approved by the CPFT research database committee. The clinical service covers a population of approximately 1 million people, including the population of Cambridgeshire and Peterborough and some surrounding counties. The mental health trust is not the sole provider of memory assessment services. The population is also served by clinics where diagnoses of dementia are made in general hospital, geriatric medicine and neurology departments, although the latter tend to focus on young-onset disease or non-Alzheimer's dementias such as Huntington's disease and frontotemporal dementia, which would not be within the scope of the treatments discussed here. In 2019, CPFT was also providing post-diagnostic and emergency support to patients diagnosed in other services, resulting in the majority of new diagnoses in the catchment area having had contact with the Trust. The imaging data was obtained from our ongoing study Quantitative MRI in NHS Memory Clinics (QMIN-MC; www.rittman.uk/qminmc). This project uses MRI scans obtained during routine NHS memory clinic appointments to develop and evaluate MRI biomarkers for clinical use, including for selection of novel treatments. The scans are all reported by a consultant neuroradiologist. To assess the burden of vascular disease, we calculated the Fazekas score[16] for all QMIN-MC MRI scans collected at our Trust.

We evaluated the replicability of our findings by using the deidentified patient record from the South London and Maudsley NHS Trust (SLaM).[17] SLaM provides comprehensive mental health services to a geographic catchment of around 1.2 million residents in four South London boroughs (Croydon, Lambeth, Lewisham and Southwark), as well as some regional and national specialist services. Although it has a similar population size to Cambridgeshire, it is an urban setting with a much greater ethnic diversity (48% non-White) and social deprivation. Cerebrovascular burden was assessed with the SLaM Image Bank data-set (www.brainregion.com/slamimagebank), and findings were extrapolated to the full SLaM cohort. This was done using free-text analysis of the imaging reports to exclude reports with a mention of 'moderate small vessel', 'extensive small vessel', 'severe small vessel', 'old infarct', 'superficial siderosis' or 'encephalomalacia', alongside manual reads of reports containing 'infarct', 'multiinfarct', 'old infarct', 'haemorrhage', 'microhaemorrhage', 'microhaemorrhages', 'bleed', 'microbleed', 'macrobleed', 'stroke', 'large vessel', 'territory', 'vasogenic oedema', 'oedema', 'lacunar', 'major vascular', 'white matter disease', 'tumour', 'space occupying', 'contusion', 'vascular malformation' and 'aneurysm'. The source data are approved for secondary analysis (Oxford REC, reference 18/SC/0372),[17] and via the National Institute for Health and Care Research (NIHR) Biomedical Research Centre Maudsley Neuroimaging Call (NQOD-04) for SLaM Image Bank access.

Results

Factors influencing numbers requiring treatment where direct data is available in our primary data-set (CPFT)

Numbers with an appropriate diagnosis

To avoid data derived from service disruption arising from the COVID-19 pandemic, we examined the calendar year 2019. During that year, CPFT received referrals for 25 567 unique individuals to mental health services. Of these, 7547 were aged between 50 and 90 years. Of those, 880 received a new diagnosis of either Alzheimer's disease with early or late onset, Alzheimer's disease atypical or mixed type, or Alzheimer's disease unspecified (ICD-10 codes: F00.0 (16), F00.1 (326), F00.2 (521) or F00.9 (17)). Similarly, 597 received a new diagnosis of mild cognitive impairment (MCI) (ICD-10 code F06.7). Forty-five received a diagnosis of MCI and a subsequent diagnosis of dementia in the same year (of which 11 received a diagnosis of vascular dementia), leaving 1432 unique individuals. This is likely to be an overestimate of patients with an appropriate diagnosis because it is questionable whether a patient with a diagnosis of atypical or mixed Alzheimer's disease would meet the criteria for entry to the trials of anti-amyloid therapy, and not all of those diagnosed with MCI would meet the criteria for MCI secondary to Alzheimer's disease. At the very least, some 15% of patients with MCI are amyloid biomarker negative,[18] meaning the total pool of potential participants would be 1349, which is a parsimonious estimate (i.e. errs on the side of inclusion). Our figure of 15% screen failure for amyloid is less than that seen in some published trials (e.g. 24% in TRAILBLAZER-ALZ2[2]), and we have only applied it to the MCI group; however, where there is a choice of data we have always selected those that predict a higher treatment population, so as to identify what might be the highest number of people we might need to accommodate for treatment rather than an underestimate. We have excluded patients on the basis of amyloid positivity at this stage of the calculation, but at what point in the process this

is assessed is important in determining the number of PET scans required.

Numbers meeting cognitive inclusion criteria

All trials included cognitive criteria for entry. CLARITY-AD used the Mini-Mental State Examination (MMSE) combined with the age-adjusted Wechsler Memory Scale IV – Logical Memory II, a measure of cognition not commonly employed in NHS clinical services.[1] TRAILBLAZER-ALZ used the MMSE alone, excluding patients whose MMSE was not in the range 20–28. MMSE scores can be converted to an estimated Addenbrooke's Cognitive Examination-Revised (ACE-R[19]) score, which is similar to the Addenbrooke's Cognitive Examination-III[20] test used in our clinics. An MMSE score of 20 equates to an ACE-R score of 52.[21] A total of 90% of patients in our service who had an ACE administered scored more than 52. This is again likely to be a conservative estimate because patients presenting late in the disease course who are very impaired would not be tested with an ACE, but instead with a more basic tool, such as the Mini-ACE. An ACE score of 52 is low and likely to include patients who would not meet the criteria for 'early' disease. Nevertheless, using the most parsimonious assumption that 90% have an appropriate cognitive score leaves a potential treatment population of 1214.

Numbers able to undergo imaging

Eligibility criteria for all trials of anti-amyloid therapy include confirmation of amyloid and sometimes tau positivity using PET or CSF, as well as structural imaging to exclude a significant burden of vascular disease. Our patients do not routinely undergo CSF examination or amyloid and/or tau PET imaging, but MRI scanning is part of the routine diagnostic work-up. We have previously published data showing that in our local service only 66% of patients undergo imaging (including those patients who had recently been imaged for other reasons).[22] The 2019 national memory service audit found the average proportion of patients in each service deemed not to need imaging was 15%.[23] If 85% of patients undergo appropriate structural imaging, this leaves 1032 of our population remaining potentially eligible for treatment.

Numbers who meet criteria for vascular burden

Our routinely collected diagnostic scans in CPFT are anonymised and available for research purposes. We examined this library to see what percentage of patients might be excluded with the imaging criteria for CLARITY-AD, i.e. 'Other significant pathological findings on the MRI scan including but not limited to: more than 4 microhaemorrhages …; a single macro haemorrhage …; an area of superficial siderosis, evidence of vasogenic edema, evidence of cerebral contusion, encephalomalacia, aneurysms, vascular malformations or infective lesions, evidence of multiple lacunar infarcts or stroke involving a major vascular territory, severe small vessel or white matter disease, space occupying lesions or brain tumors …'.[1] Of 100 available scans stored for research purposes with a diagnosis of MCI or Alzheimer's disease, 49% had a total Fazekas score of 4 or more and 40% had a deep white matter lesion score of 2 or more. Applying the latter of these two figures decreases the total potential patient pool for treatment to 619.

Numbers excluded for other reasons

Other exclusion criteria from CLARITY-AD included pregnancy, neurological conditions adding to cognitive impairment beyond Alzheimer's disease, history of transient ischaemic attack stroke or seizures within 12 months of screening, psychiatric diagnosis that could interfere with treatment, geriatric depression scale score ≥8, concomitant treatment with biological treatment, bleeding disorders, vitamin B12 or thyroid-stimulating hormone abnormalities, HIV positivity, malignant neoplasms within 3 years of screening, suicidal ideation, other abnormalities, drug or alcohol misuse, planned surgery, severe sensory impairment or participation in other trials was either not known and/or not thought likely to be as a significant contributor to limiting treatment.[1]

We examined the data for comorbid ICD-10 diagnostic F codes (mental, behavioural and neurodevelopmental disorders), and 68 patients had a recorded diagnosis of delirium, 17 patients had depressive disorder and 13 patients had mixed anxiety and depression. All other psychiatric diagnostic categories yielded fewer than ten individuals. Although the additional exclusion criteria might reduce the potential treatment population further, we do not have data to address all of them and it seems unlikely any one would exclude a large number of patients, so we did not adjust the total potential treatment population.

Factors influencing numbers requiring treatment where indirect data is available

Further questions arise as to how many of those eligible would be willing to undergo the requirements of treatment. These include repeat imaging and a fortnightly or monthly intravenous infusion with significant risk of side effects. A parsimonious approach might be to look at how many patients with a diagnosis of Alzheimer's disease currently receive oral symptomatic treatments such as donepezil and memantine. Previously, we showed that 65% of eligible patients are prescribed these medicines in our service, comparable to larger data-sets such as the National 2019 Memory Service Audit, which found that 83% of eligible patients were offered currently available medication, of which 90% accepted, meaning that 75% of the overall sample received treatment.[22,23] Applying the more generous 75% cut-off leaves a pool of 464 patients to receive treatment. Of course, it may be that patients would be more willing to take a disease-modifying treatment, which would increase numbers, or that contraindications to existing treatments may not apply to new ones, but it is probably more likely that the significant extra burden of imaging, intravenous treatment and safety scans means 75% is a number that errs strongly on the side of inclusion.

Using real data from the service in Cambridgeshire, but taking a parsimonious view of patient selection at every point to give the greatest possible treatment population, results in a total maximum potential treatment population of 464 from a total number of new diagnoses of 1432. This is in the context of the 70% screen failure rate in CLARITY-AD (which, if applied to all new diagnoses in our service, would suggest a potential treatment population of 430) and 87% in TRAILBLAZER-ALZ (a potential treatment population of 186). Based on our data, we might expect a maximum of 464 people starting treatment in Cambridgeshire per year.

The duration of therapy beyond the 18 months for which there is an established evidence base remains unclear. To date, no stopping criteria for anti-amyloid therapy have been described, although there is a suggestion that treatment should not be continued once patients develop moderate dementia (defined as progression to a Clinical Dementia Rating Scale global score of 2.0, MMSE score <20 and loss of autonomy in key activities of daily living) because of a lack of evidence of efficacy at this stage of the condition.[13] Patients in the TRAILBLAZER-ALZ 2 trial stopped infusion when amyloid was supressed below a threshold, meaning around a third ceased treatment after 6 months.[2] Patients with Alzheimer's disease spend between 2 and 6 years in the mild dementia stage, which depends on factors such as gender, age at diagnosis and ApoE4 status.[24] Amyloid burden and the occurrence of ARIA

may also influence when treatment is stopped. Ongoing clinical trials will hopefully shed light on whether maintenance therapy is required, or whether treatment can stop when patients become amyloid negative. The majority of ARIA-E (oedema or effusions) occurred in the first few months of lecanemab treatment (71% occurred within 3 months[1]), so this is unlikely to contribute to later drop-outs. However, isolated ARIA-H (cerebral microhaemorrhages, macrohaemorrhages or superficial siderosis) occurred more randomly during the treatment course, and at a similar rate for the lecanemab (8.9%) and placebo (7.8%) groups.[1] If future stopping criteria includes the development or extent of ARIA-H, then this will increase the number of people who drop out. In CLARITY-AD, patients were treated with lecanemab for 18 months and had a 10% per year all-cause drop-out rate; this rate is likely to be higher in a clinical setting than in a trial.[1]

If we assume 464 patients starting treatment each year, and a maximal mean treatment period of 3 years with infusions occurring fortnightly, then the numbers requiring treatment would reach steady state at year three, with 1258 individuals needing 629 treatments per week or 90 per day for Cambridgeshire and Peterborough. The numbers of infusions would be halved in the event of monthly treatment, and lower still if treatment is stopped once amyloid is suppressed.

Factors influencing numbers requiring treatment where no data is available

There are a number of further factors that are impossible to know or use data to predict. One is whether the advent of potentially disease-modifying treatment might encourage more people to present for assessment. If that were to happen, then memory clinics in the UK struggling to meet current demand would need scaling up to meet this increased need within a reasonable time frame. For example, in the most recent UK National Memory Assessment Audit, the average time to diagnosis was over 17 weeks, with a range of 0–104 weeks.[10] If patients move from a point in disease beyond that where treatment is possible during the waiting period, this will not be acceptable. Availability of these treatments may increase willingness to undergo investigation such as brain scans, with attendant pressure on these services. Further unknowns are whether recent advances in blood biomarkers might obviate the need for PET imaging or CSF analysis for entry, or whether the advent of a treatment administered subcutaneously might increase demand. It is possible that decisions around licensing and access may be influenced by data from trials of subgroups of patients. For example, consideration has been given to whether funding might be restricted for ApoE4 homozygotes, where the balance of risk and benefit might differ, which would screen out a further 2% of the population.[11] Finally, we have considered the use of these medicines only within the criteria used in their clinical trials, as it is important to use them only in the context within which they have been shown to be of benefit. However, there is a history of drugs being used more widely post-licensing, with consequent increased use and resource requirement.

Replication

To validate our findings in a second independent data-set, we applied the same assumptions to the SLaM anonymised patient record and SLaM Image Bank data-set. In the year 2019, SLaM received 56 819 referrals, of which 11 489 were aged 50–90 years. Of these, 1880 received a diagnosis that would qualify them for treatment. After removing 15% of patients with MCI assumed to be amyloid negative, 876 met the threshold in cognitive tests and 745 were expected to undergo neuroimaging. Within the cohort, 115 had neuroimaging available for analysis, with 24 patients (21%) being excluded on the basis of significant vascular

burden. Extrapolating this to the full SLaM cohort leaves a total potential treatment population of 589. If 75% accept treatment, the number starting treatment each year would be 442, a similar number to those starting treatment in Cambridgeshire. The results from the two Trusts are summarised in Fig. 1. Taken together, these two Trusts cover around 2.2 million (3%) of the UK's total population of 67 million. Therefore, our calculations suggest an annual demand of 30 200 people starting treatment each year in the UK, a much lower number than previous estimates reported in the press. Although this is the potential treatment population, in reality, initial treatment uptake is likely to be slow and patchy as patients, clinicians and services adapt to any new treatments becoming available, with use slowly increasing over time.

Discussion

We have used available data to make the best possible prediction of maximal potential demand for new Alzheimer's disease treatments for two large NHS trusts in the UK, which we have extrapolated nationally. These figures are based on hard data as far as possible, although inevitably they also require some assumptions. Where assumptions have been made, we have attempted to explain our careful reasoning, and the calculation can be easily adjusted using different parameters as new information comes to light or if people choose to make different assumptions. The numbers may cause concern for services already struggling to meet current demand. However, it is worth making a comparison with use of monoclonal antibodies for other conditions. According to the local prescribing data for Cambridgeshire and Peterborough, 432 new patients were treated with monoclonal antibodies for inflammatory bowel disease in 2022. Although this is similar to our calculated demand for Alzheimer's disease, most monoclonal antibodies are administered subcutaneously less frequently than every 2 weeks, for shorter periods of time and do not need MRI monitoring for side-effects. Nevertheless, the challenge posed by monoclonal antibodies for Alzheimer's disease is not out of keeping, in terms of scale, with these agents being used in other conditions.

One significant issue might be the availability of structural neuroimaging before treatment. National Institute for Health and Care Excellence (NICE) guidance[25] for the diagnosis of dementia recommends neuroimaging but does not specify the modality, i.e. MRI or computed tomography. National audits suggest that 74% of NHS memory services use computed tomography rather than MRI scans, so routine availability of MRI scans will limit access to treatment.[23] This would be further underlined if treatment requires serial MRI scanning after initiation, which seems likely with a minimum of four scans recommended in the USA. The potential need for PET scanning to identify appropriate patients for treatment would likely be an even greater issue. The number of PET scans required would depend where on the pathway to determine eligibility they are placed, but even if applied only to those that have met all other inclusion criteria, this would be hundreds of PET scans per year regionally and tens of thousands nationally, as the number of scans for eligibility will be greater than the number of those eligible for treatment by up to 25%.[2] These requirements for imaging would be challenging, perhaps even impossible, given current resources. This difficulty might be ameliorated by the use of CSF examination (which would itself provide new issues) or blood biomarkers to identify patients, but it would currently present a rate-limiting step in access. The phase three trial results also suggest an altered risk of ARIA depending on ApoE genotype.[1,2] It seems likely that this genetic information would be helpful in informing patients and scaling up the facility for testing, and appropriate counselling would present a further challenge to health services not currently
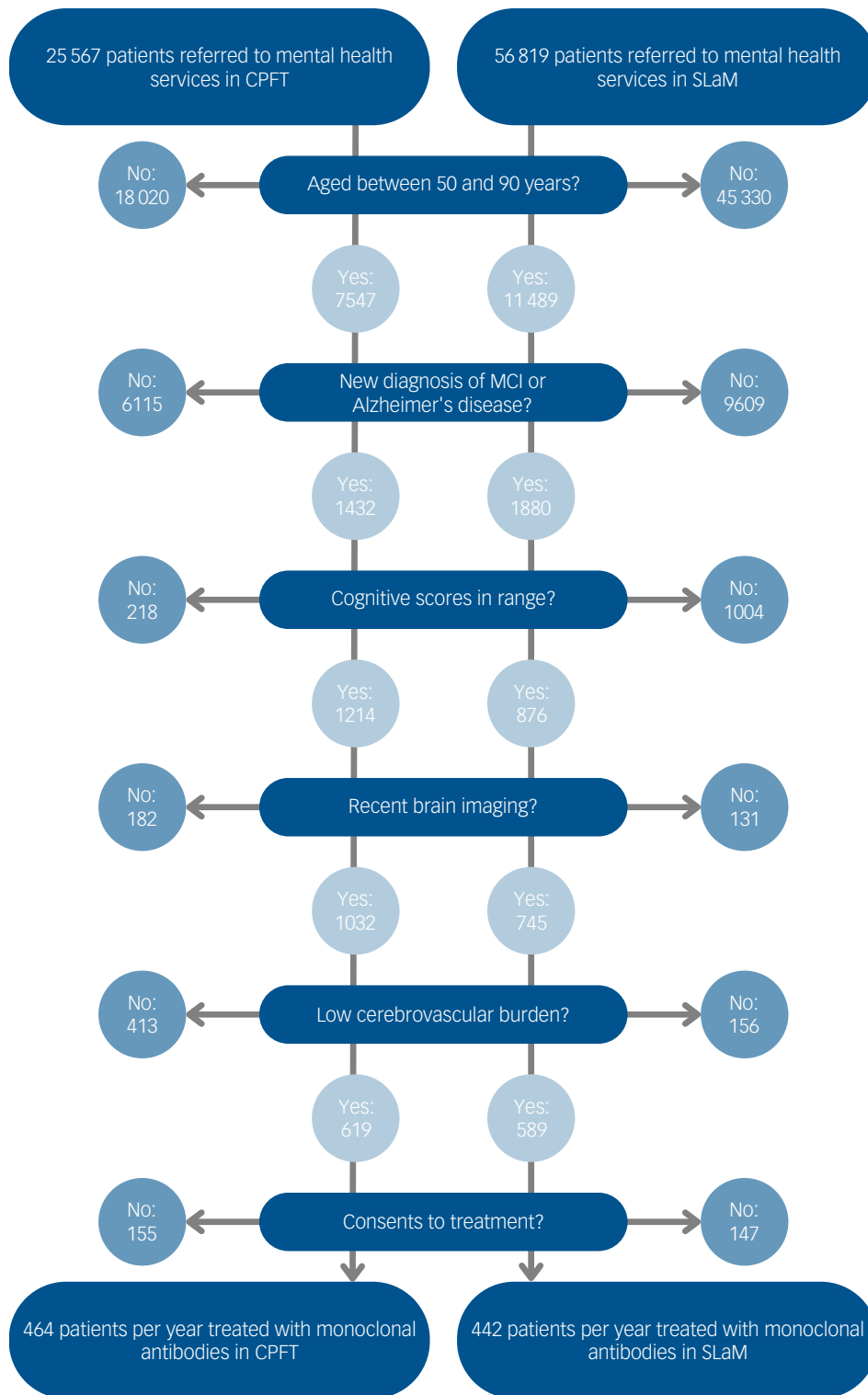
Fig. 1 Flow diagram showing the number of patients in Cambridgeshire and Peterborough NHS Foundation Trust (CPFT) and South London and Maudsley NHS Trust (SLaM) who would receive treatment with monoclonal antibodies for Alzheimer's disease. MCI, mild cognitive impairment.

routinely providing this. ApoE genotyping is already included in some 'appropriate use' recommendations.[12,13]

Whether these drugs or other monoclonal antibodies for Alzheimer's disease are licensed in the UK, approved by NICE and accepted by patients based on the balance of benefits and risks remains to be seen. If approved they would undoubtedly present a significant challenge to deliver, particularly given existing service pressures, but the challenge would not be completely out

of keeping with the delivery of similar biologic treatments for other conditions, such as inflammatory bowel disease, cancer or multiple sclerosis, where new treatments have been shown to be cost-effective. Although the clinical benefit of the current generation of anti-amyloid drugs appears marginal, if they are licensed and can demonstrate cost-effectiveness, which must include the costs to healthcare systems of setting up and maintaining the delivery infrastructure as well as the price of the drug itself, then they should be

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made available to patients on an equitable basis. We believe the data presented here is the best estimate of potential demand to date, and we hope that it will support healthcare planners and policy makers in preparing for any future delivery of these drugs.

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Data availability

No analytic code was used in the analysis of raw data, and all calculations are shown in the main body of the paper. Source code for extracting the original data from the database is available from the corresponding author, B.R.U., on reasonable request. Raw de-identified data are not publicly available, under the terms of NHS Research Ethics approvals; for details of access and conditions, contact research.database@cpft.nhs.uk.

Author contributions

B.R.U. designed the study. B.R.U., T.R., T.S., M.M., J.L., C.M., A.A.S.L. and A.V.V. were responsible for data collection and analysis. B.R.U., A.A.S.L., A.V.V., T.R., J.D.I., M.S.K., R.B., C.M. and R.S. drafted the manuscript. B.R.U., A.A.S.L. and A.V.V. revised the manuscript.

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Declaration of interest

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