Research Square

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Plasma Amyloid-β Oligomerization Tendency Predicts Amyloid PET Positivity

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Abstract

Background: Among other emerging amyloid-targeting blood-based biomarkers, Multimer Detection System-Oligomeric Amyloid-β (MDS-OAβ) measures dynamic changes in concentration of oligomeric amyloid-β (OAβ), which is considered the main pathogenic culprit of Alzheimer's disease (AD), in plasma after spiking with synthetic amyloid-β (Aβ). We aimed to investigate predictability of MDS-OAβ on amyloid Positron Emission Tomography (PET) positivity.

Methods: A total of 96 subjects who visited Seoul National University Bundang Hospital for medical check-up complaining of cognitive decline and had undergone extensive medical assessment were recruited. Amyloid statuses were dichotomized into positive or negative based on visual assessment of amyloid PET. Plasma OAβ concentration was measured by MDS-OAβ. In the previous validation study, 0.78ng/ml was established as the cut-off value and the plasma OAβ concentration higher than or equal to the cut-off value was defined MDS-OAβ positive.

Results: MDS-OAβ positivity could discriminate amyloid PET positivity with the AUC value of 0.855 (95% CI 0.776–0.933). Adding MDS-OAβ positivity to prediction models including age, MMSE score, and APOE ε4 status improved the performance up to the AUC value of 0.926 (95% CI 0.871–0.980).

Conclusions: The Aβ oligomerization tendency in plasma could predict amyloid PET positivity with high performance, and when it is combined with age, MMSE score, and APOE ε4 status, the predictability was improved substantially. This suggests the potential of MDS-OAβ as a useful initial stage test in clinical and research field of AD.

Background

Brain amyloidopathy is a hallmark of Alzheimer's disease (AD) and pathologic changes associated with amyloid-β (Aβ) is known to start 10–20 years prior to clinical manifestation [1,2]. Due to such long period of progressive pathological changes without symptoms, prediction of disease progression has always been a challenge. Also, as clinical trials on disease-modifying treatment have not shown satisfactory results, the necessity to advance the stage of therapeutic target population towards early AD stage as well as the importance of early detection of amyloidopathy have been emphasized.

Currently, brain amyloidopathy is assessed by amyloid positron emission tomography (PET) and cerebrospinal fluid (CSF) biomarker test [3]. However, their high cost and invasiveness limit their utility in spite of increased needs and hence, the development of an AD biomarker which could overcome such limitations has been long anticipated. There have been efforts to develop an amyloid-targeting blood-based biomarker in order to provide better accessibility in the research and primary care fields and blood-based biomarkers have shown promising potential in their utility in the prediction of amyloidopathy [4].

Multimer Detection System-Oligomeric Amyloid-β (MDS-OAβ) is a modified atypical sandwich immunoassay for measuring Aβ oligomerization in plasma [5]. MDS was originally developed as a

means to detect prion oligomers in the blood of scrapie-infected animals, which selectively detect oligomers over monomers. The technique was further modified by spiking synthetic Aβ into plasma prior to the antigen-antibody reaction to measure oligomerization tendency of plasma Aβ. It measures the dynamic change of plasma oligomeric Aβ concentration which is higher in AD patients compared to normal healthy controls [5,6]. In previous studies MDS-OAβ could differentiate AD from normal control group with high sensitivity and specificity [5,6].

In this study, we aimed to evaluate the predictability of plasma Aβ oligomerization tendency measured by MDS-OAβ on brain amyloidopathy.

Methods

Subjects

We included subjects who visited the Neurocognitive Behavior Center of the Seoul National University Bundang Hospital, Republic of Korea, between May 2014 and May 2020 for medical check-up out of complaints on cognitive decline and had undergone extensive evaluation of cognitive function, that contained physical, neurological, neuropsychological, genetic (*APOE* genotyping) and biomarker analyses including brain magnetic resonance imaging, amyloid PET, and MDS-OAβ. Patients who have not undergone amyloid PET or MDS-OAβ were excluded from this study. Subjects consisted of 54 probable AD dementia patients according to the National Institute on Aging-Alzheimer's Association criteria [7], 27 mild cognitive impairment (MCI) patients according to the National Institute on Aging-Alzheimer's Association criteria [8], 7 subjective cognitive decline (SCD) patients according to the guideline by Jessen et al. [9], 8 other neurodegenerative diseases as a disease control group including 4 frontotemporal dementia (FTD) patients [10,11], 1 corticobasal syndrome (CBS) patient [12], 1 Parkinson's disease dementia (PDD) patient [13], and 2 progressive supranuclear palsy (PSP) patients [14]. Written informed consent was obtained from all subjects or their caregivers. This study was approved by the institutional review board of the Seoul National University Bundang Hospital (B-2004-604-305).

Blood sampling and MDS-OAβ measurement

Blood was collected in 10-ml sodium heparin-containing tubes (BD-367874; BD Bioscience, San Jose, CA, USA) and centrifuged at 1500×g for 10 minutes at room temperature. The time interval between the blood sampling and centrifugation was maximal 3 hours. The plasma supernatant was aliquoted and stored in screw cap microtubes (polypropylene, SARSTEDT, Ref. number: 72.690) at -80°C until further analysis.

The MDS-OAβ measurement was performed using the inBlood^{TM} OAβ test (PeopleBio Inc., Gyeonggi-do, Republic of Korea) with heparin-treated plasma samples. The inBlood^{TM} OAβ test is a modified sandwich Enzyme-Linked Immunosorbent Assay (ELISA) for measuring oligomerization tendency using two epitope-overlapping antibodies specific for the N-terminus of Aβ. The antibodies used are mouse monoclonal 6E10 (BioLegend, San Diego, CA, USA) and WO-2-HRP (Absolute Antibody Ltd, Oxford, UK) and the epitopes for these antibodies overlap at the N-terminus of Aβ. 6E10, the capturing antibodies are

coated on the wells of the 96-well plate to initially capture heterogenous forms of Aβ. WO-2-HRP, the detection antibodies are added after the first antigen-antibody reaction and three rounds of washing to detect oligomeric forms of Aβ and produce signal via chemiluminescence.

Prior to the assay, plasma samples were thawed at 37°C for 15min. PBR-1 (synthetic Aβ made by PeopleBio Inc.) was then spiked into plasma and the mixture was incubated 37°C for 48 hours. The incubated plasma sample mixture and serially diluted standard samples were added to respective wells, and the plates were incubated at room temperature for 1 hour. Afterward, 100 µl/well of enhanced chemiluminescence substrate solution (Rockland Immunochemicals Inc., Limerick, PA, USA) was added, and the Relative Luminescence Unit (RLU) signal was detected using Victor 3^{TM} multi-spectrophotometer. Dilutions providing signal in the linear range of the standard curves were used for the conversion to RLU values to determine the concentration of oligomerized Aβ. All tests were completed in duplicate and the average was used. 0.78 ng/ml was established as the cut-off value in the previous validation study and the plasma OAβ concentration equal to, or higher than the cut-off value was defined as MDS-OAβ positive [6]. MDS-OAβ tester was blinded to clinical information including demographics and diagnosis.

Amyloid status

Amyloid status was evaluated by amyloid PET. [18F]Florbetaben (n=82), [18F]Flutemetamol (n=6), [18F]Florbetapir (n=2), and [11C]Pittsburgh compound B (PiB; n=1) were used as ligands. Amyloid status was defined as positive (abnormal) or negative (normal) after visual assessment by one experienced nuclear medicine physicians and two neurologists.

Statistical analysis

Baseline characteristics between amyloid normal and abnormal group were compared using chi-squared tests, Mann-Whitney U tests as appropriate. The predictive ability of MDS-OAβ and covariates on amyloid PET positivity was assessed by binary logistic regression models and presented as area under the curve (AUC) values by receiver operating characteristic (ROC) analysis. All statistical analyses were performed by R (version 4.0.0) and statistical significance was set at 0.05.

Results

Demographics and clinical characteristics

A total of 96 subjects were included in the study. The average age of total subjects was 71.50 ± 9.73 years old, and 42 subjects (43.8%) were male. Among total cohort 68 (70.8%) subjects presented amyloid-positive and 28 subjects were amyloid-negative. Comparison of baseline characteristics between groups is demonstrated in Table 1. There was no significant difference in age, sex, education level, and frequency of *APOE ε*4 carrier between groups. Amyloid-positive groups showed poor MMSE scores reflecting poor general cognitive function, and higher CDR and CDR-SOB indicating increased disease severity. Correspondingly, amyloid-positive group contained more AD patients than amyloid-negative group.

Amyloid-positive group presented significantly higher MDS-OAβ value with plasma oligomeric Aβ concentration of 0.88 ng/ml than amyloid-negative group with 0.68 ng/ml (Figure 1).

Table 1. Demographics and clinical characteristics of subjects

	Amyloid-negative (N=28)	**Amyloid-positive (N=68)**	***p* value**
Age, years	74.00 (70.50–79.00)	70.00 (61.00–75.50)	0.058
Male, n (%)	13 (46.43)	29 (42.65)	0.910
Education, years	16.00 (12.00–16.00)	16.00 (12.00–16.00)	0.783
*APOEε*4 carrier, n (%)	9 (36.0)	32 (55.17)	0.173
Diagnosis			<0.001
AD/MCI/SCD/OND*, n	4/11/6/7	50/16/1/1	
MMSE	24.00 (20.00–26.00)	19.00 (11.00–25.00)	0.016
CDR	0.5 (0.5–0.75)	1.0 (0.5–1.0)	0.003
CDR-SOB	3.0 (2.0–4.25)	6.0 (2.0–8.0)	0.014
MDS-OAβ, ng/ml	0.68 (0.52–0.77)	0.88 (0.80–0.97)	<0.001

Data are presented as the median (interquartile range) unless otherwise specified.

* OND includes FTD, PSP, PDD, and CBS.

AD; Alzheimer's Disease, CBS; Corticobasal Syndrome, CDR; Clinical Dementia Rating, CDR-SOB; Clinical Dementia Rating Sum of Boxes, FTD; Frontotemporal Dementia, MCI; Mild Cognitive Impairment, MMSE; Mini-Mental-State-Examination, MDS-OAβ; Multimer Detection System-Oligomeric Amyloid-β, OND; Other Neurodegenerative Disease, PDD; Parkinson's Disease Dementia, PSP; Progressive Supranuclear Palsy, SCD; Subjective Cognitive Decline.

Figure 1. Concentration of plasma MDS-OAβ according to groups

AD; Alzheimer's Disease, MCI; Mild Cognitive Impairment, MDS-OAβ; Multimer Detection System-Oligomeric Amyloid-β, OND; Other Neurodegenerative Disease, SCD; Subjective Cognitive Decline.

MDS-OAβ as a predictor of amyloid status

MDS-OAβ positivity could differentiate amyloid-positive subjects from amyloid-negative subjects with sensitivity of 85.3% and specificity of 85.7% (AUC= 0.855, 95% CI = 0.776–0.933). Multivariate models with MDS-OAβ positivity and other covariates including age, MMSE score, and *APOE ε*4 status showed

much better performance with AUC values between 0.892 and 0.926 than multivariate models without MDS-OAβ positivity (Table 2). Among various combinations of predictors, MDS-OAβ positivity combined with age, *APOE ε*4 status, and MMSE score demonstrated the highest AUC value of 0.926 (0.871–0.980).

MDS-OAβ positivity alone presented better predictability than MMSE alone (AUC= 0.657, 95% CI = 0.545–0.769). Although, when combined with age and *APOE ε*4 status, the AUC value for MMSE increased to 0.740 (95% CI = 0.626–0.853), this was not statistically significant compared with MMSE alone. However, when the combination of predictors were added with MDS-OAβ positivity, predictive performance improved significantly (AUC= 0.926, 95% CI = 0.871–0.980) (Figure 2. A). When combining objective factors such as age and *APOE ε*4 status with MDS-OAβ positivity, the predictability on amyloid PET positivity was strengthened (Figure 2. B).

Table 2. Performance of predictors for amyloid PET positivity with and without MDS-OAβ positivity

Predictors	AUC (95% CI)	Sensitivity (%)	Specificity (%)
MMSE	0.657 (0.545–0.769)	54.4	82.1
age + MMSE	0.681 (0.572–0.789)	47.1	89.3
age + *APOEε*4	0.684 (0.552–0.816)	77.6	60.0
age + *APOEε*4 + MMSE	0.740 (0.626–0.853)	56.9	84.0
MDS-OAβ positivity	0.855 (0.776–0.933)	85.3	85.7
MMSE + MDS-OAβ positivity	0.892 (0.820–0.963)	86.8	85.7
age + MMSE + MDS-OAβ positivity	0.922 (0.863–0.981)	91.2	82.1
age + *APOE ε*4 + MDS-OAβ positivity	0.912 (0.844–0.980)	74.1	96.0
age + *APOE ε*4 + MMSE + MDS-OAβ positivity	0.926 (0.871–0.980)	74.1	96.0

AUC; area under the curve, CI; confidential interval, MMSE; Mini-Mental-State-Examination, MDS-OAβ; Multimer Detection System-Oligomeric Amyloid-β

Figure 2. Receiver Operating Characteristic analysis of MDS-OAβ positivity with other predictors on amyloid PET positivity

1. Added MDS-OAβ positivity to clinical information such as age, MMSE score, and *APOE ε*4 status, predictability for amyloid PET positivity improves. B. Considered only objective factors such as age and *APOE ε*4 status, combining with MDS-OAβ positivity strengthened the predictability on amyloid PET positivity

MDS-OAβ; Multimer Detection System-Oligomeric Amyloid-β, MMSE; Mini-Mental-State-Examination.

Discussion

In this study, we found that MDS-OAβ positivity could discriminate amyloid PET positivity with the AUC value of 0.855. Furthermore, adding MDS-OAβ positivity to prediction models including age, MMSE score, and *APOE ε*4 status improved the performance significantly up to the AUC value of 0.926.

Substantial effort to detect and measure amyloid-β in the blood has been made and several assays stood as promising candidates for blood-based biomarkers [4]. Theses assays principally aimed to quantify the concentration of $A\beta_{42}$ and $A\beta_{42}/A\beta_{40}$. However, they have been employed in a limited capacity due to several unique characteristics of this protein, such as its scarcity in the blood [15] and tendency to self-aggregate [16] as well as of the blood matrix such as the abundance of various Aβ-binding proteins in the blood [17], which interfere the detection of Aβ.

MDS-OAβ, on the other hand, takes a distinct approach to possibly overcome the said challenges. It measures the Aβ oligomerization tendency of plasma by implementing the spiking of synthetic Aβ [5], prior to selective detection of Aβ oligomers, reputedly the main pathogen of AD [18], over Aβ monomers using epitope-overlapping antibodies. It is highly anticipated that this technique shall bring the unprecedented solution to detection and monitoring of AD-related amyloid dynamics in the blood.

Discriminative performance of MDS-OAβ between AD and normal control group was demonstrated in previous studies. In the study by An and his colleagues, MDS-OAβ assay mechanism and its diagnostic performance were evaluated. AD group (n=27) was differentiated from age-matched normal control group (n=144) with AUC of 0.896 (sensitivity 83.3%, specificity 90.0%) [5]. A recent validation study with AD (n=52) and normal control (n=52) confirmed the diagnostic accuracy with AUC value of 0.999 (sensitivity 100%, specificity 92.31%) [6]. The current study was completed in more heterogeneous population including individuals with AD, MCI, SCD, or other neurodegenerative diseases, and predictability on amyloid PET positivity was comparable (AUC 0.855). In various combinations with age, MMSE scores, and *APOE ε*4 status AUC values increased between 0.892 and 0.926. These are also comparable with or even better than performance of other amyloid-targeting blood-based assays

including immunoprecipitation followed by mass spectrometry [19,20], single-molecule arrays [21,22], and immune-infrared-sensor [23,24].

Another interesting finding was that the predictability on amyloid PET positivity was considerably enhanced when combining MDS-OAβ positivity with age and MMSE scores with the AUC increasing to 0.922, whereas the predictability of age and MMSE scores combined had only AUC of 0.681 (95% CI 0.572–0.789). In clinical settings such as primary care, age and MMSE scores might be the only accessible information, and transfer of patients to specialized memory clinic for further work-up often rely on limited information based on MMSE score and age. A blood test such as MDS-OAβ which has good predictability on amyloid PET positivity could be implemented as an early stage AD blood test to relieve such drawback and be utile in terms of screening the patients in advance of further diagnostic examination.

There were several limitations in this study. This study presented small sample size, especially for each diagnostic group. Additionally, our cohort showed relatively high prevalence of amyloid PET positivity and amyloid-positive group tended to be younger than amyloid-negative group. Younger patients with cognitive decline might have undergone amyloid PET more frequently than older patients during the diagnostic process, and this could have contributed to the characteristic of our cohort.

Conclusion

In summary, Aβ oligomerization tendency in plasma measured by MDS-OAβ could predict amyloid PET positivity (AUC= 0.855, 95% CI = 0.776–0.933). Furthermore, when MDS-OAβ positivity is combined with clinical information such as age, MMSE score, and APOE ε4 status, predictability for amyloid PET positivity was improved (AUC= 0.926, 95% CI = 0.871–0.980). This suggests the potential of MDS-OAβ as a useful initial stage test in clinical and research field of AD.

Abbreviations

AD; Alzheimer's Disease, CBS; Corticobasal Syndrome, CDR; Clinical Dementia Rating, CDR-SOB; Clinical Dementia Rating Sum of Boxes, FTD; Frontotemporal Dementia, MCI; Mild Cognitive Impairment, MMSE; Mini-Mental-State-Examination, MDS-OAβ; multimer detection system-oligomeric amyloid-β, OND; Other Neurodegenerative Disease, PDD; Parkinson's Disease Dementia, PSP; Progressive Supranuclear Palsy, SCD; Subjective Cognitive Decline

Declarations

Ethics approval and consent to participate

This study was approved by the institutional review board of the Seoul National University Bundang Hospital (B-2004-604-305). Written informed consent was obtained from all subjects or their caregivers.

Consent for publication

Not applicable

Availability of data and materials

The study data are not publicly available for download, might be retrieved from corresponding author professor SangYun Kim.

Competing interests

All authors declare no competing interests.

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Authors' contributions

JMP analyzed, interpreted data and drafted the work. JSR and RL contributed to the acquisition of data and revision of the manuscript. KHS, YHP and YCY interpreted data and revised the manuscript. NR and SSAA revised the manuscript. SYK designed the work, interpreted data, and revised the manuscript. All authors read and approved the final manuscript.

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Not applicable

References

1. Jack CR, Knopman DS, Jagust WJ, Petersen RC, Weiner MW, Aisen PS, et al. Tracking pathophysiological processes in Alzheimer's disease: An updated hypothetical model of dynamic biomarkers. Lancet Neurol. 2013,12.2.
2. Bateman RJ, Xiong C, Benzinger TLS, Fagan AM, Goate A, Fox NC, et al. Clinical and Biomarker Changes in Dominantly Inherited Alzheimer's Disease. N Engl J Med. 2012,367.
3. Jack CR, Bennett DA, Blennow K, Carrillo MC, Dunn B, Haeberlein SB, et al. NIA-AA Research Framework: Toward a biological definition of Alzheimer's disease. Alzheimer's Dement. Elsevier Inc.; 2018,14.4.
4. Pyun J-M, Kang MJ, Ryoo N, Suh J, Youn YC, Park YH, et al. Amyloid Metabolism and Amyloid-Targeting Blood-Based Biomarkers of Alzheimer's Disease. J Alzheimer's Dis. 2020;75.
5. An SSA, Lee BS, Yu JS, Lim K, Kim GJ, Lee R, et al. Dynamic changes of oligomeric amyloid β levels in plasma induced by spiked synthetic Aβ42. Alzheimer's Res Ther. 2017,9.1.

6. Youn YC, Lee BS, Kim GJ, Ryu JS, Lim K, Lee R, et al. Blood Amyloid-β Oligomerization as a Biomarker of Alzheimer's Disease: A Blinded Validation Study. J Alzheimer's Dis. 2020,75.2.
7. McKhann GM, Knopman DS, Chertkow H, Hyman BT, Jack CR, Kawas CH, et al. The diagnosis of dementia due to Alzheimer's disease: Recommendations from the National Institute on Aging-Alzheimer's Association workgroups on diagnostic guidelines for Alzheimer's disease. Alzheimer's Dement. 2011,7.3.
8. Albert MS, DeKosky ST, Dickson D, Dubois B, Feldman HH, Fox NC, et al. The diagnosis of mild cognitive impairment due to Alzheimer's disease: Recommendations from the National Institute on Aging-Alzheimer's Association workgroups on diagnostic guidelines for Alzheimer's disease. Alzheimer's Dement. 2011,7.3.
9. Jessen F, Amariglio RE, Van Boxtel M, Breteler M, Ceccaldi M, Chételat G, et al. A conceptual framework for research on subjective cognitive decline in preclinical Alzheimer's disease. Alzheimer's Dement. 2014,10.6.
10. Rascovsky K, Hodges JR, Knopman D, Mendez MF, Kramer JH, Neuhaus J, et al. Sensitivity of revised diagnostic criteria for the behavioural variant of frontotemporal dementia. Brain. 2011,134.9.
11. Gorno-Tempini ML, Hillis AE, Weintraub S, Kertesz A, Mendez M, Cappa SF, et al. Classification of primary progressive aphasia and its variants. Neurology. 2011,76.11.
12. Armstrong MJ, Litvan I, Lang AE, Bak TH, Bhatia KP, Borroni B, et al. Criteria for the diagnosis of corticobasal degeneration. Neurology. 2013,80.5.
13. Dubois B, Burn D, Goetz C, Aarsland D, Brown RG, Broe GA, et al. Diagnostic procedures for Parkinson's disease dementia: Recommendations from the Movement Disorder Society Task Force. Mov Disord. 2007,22.16.
14. Litvan I, Agid Y, Calne D, Campbell G, Dubois B, Duvoisin RC, et al. Clinical research criteria for the diagnosis of progressive supranuclear palsy (Steele-Richardson-Olszewski syndrome): Report of the NINDS-SPSP International Workshop. Neurology. 1996,47.1.
15. Toledo JB, Vanderstichele H, Figurski M, Aisen PS, Petersen RC, Weiner MW, et al. Factors affecting Aβ plasma levels and their utility as biomarkers in ADNI. Acta Neuropathol. 2011,122.4.
16. Serem WK, Bett CK, Ngunjiri JN, Garno JC. Studies of the growth, evolution, and self-aggregation of β-amyloid fibrils using tapping-mode atomic force microscopy. Microsc Res Tech. Microsc Res Tech. 2011,74.7.
17. Kuo YM, Emmerling MR, Lampert HC, Hempelman SR, Kokjohn TA, Woods AS, et al. High levels of circulating Aβ42 are sequestered by plasma proteins in Alzheimer's disease. Biochem Biophys Res Commun. 1999,257.3.
18. Cline EN, Bicca MA, Viola KL, Klein WL. The Amyloid-β Oligomer Hypothesis: Beginning of the Third Decade. J Alzheimer's Dis. 2018, 64.
19. Ovod V, Ramsey KN, Mawuenyega KG, Bollinger JG, Hicks T, Schneider T, et al. Amyloid β concentrations and stable isotope labeling kinetics of human plasma specific to central nervous system amyloidosis. Alzheimer's Dement. 2017,13.8.

20. Nakamura A, Kaneko N, Villemagne VL, Kato T, Doecke J, Doré V, et al. High performance plasma amyloid-β biomarkers for Alzheimer's disease. Nature. 2018,554.7691.
21. Verberk IMW, Slot RE, Verfaillie SCJ, Heijst H, Prins ND, van Berckel BNM, et al. Plasma Amyloid as Prescreener for the Earliest Alzheimer Pathological Changes. Ann Neurol. 2018,84.5.
22. Vergallo A, Mégret L, Lista S, Cavedo E, Zetterberg H, Blennow K, et al. Plasma amyloid β 40/42 ratio predicts cerebral amyloidosis in cognitively normal individuals at risk for Alzheimer's disease. Alzheimer's Dement. 2019,15.6.
23. Nabers A, Ollesch J, Schartner J, Kötting C, Genius J, Hafermann H, et al. Amyloid-β-Secondary Structure Distribution in Cerebrospinal Fluid and Blood Measured by an Immuno-Infrared-Sensor: A Biomarker Candidate for Alzheimer's Disease. Anal Chem. 2016,88.5.
24. Güldenhaupt J, Brenner H, Janelidze S, Lange J, Schartner J, Nabers A, et al. Amyloid blood biomarker detects Alzheimer's disease. EMBO Mol Med. 2018,10.5.

Figures

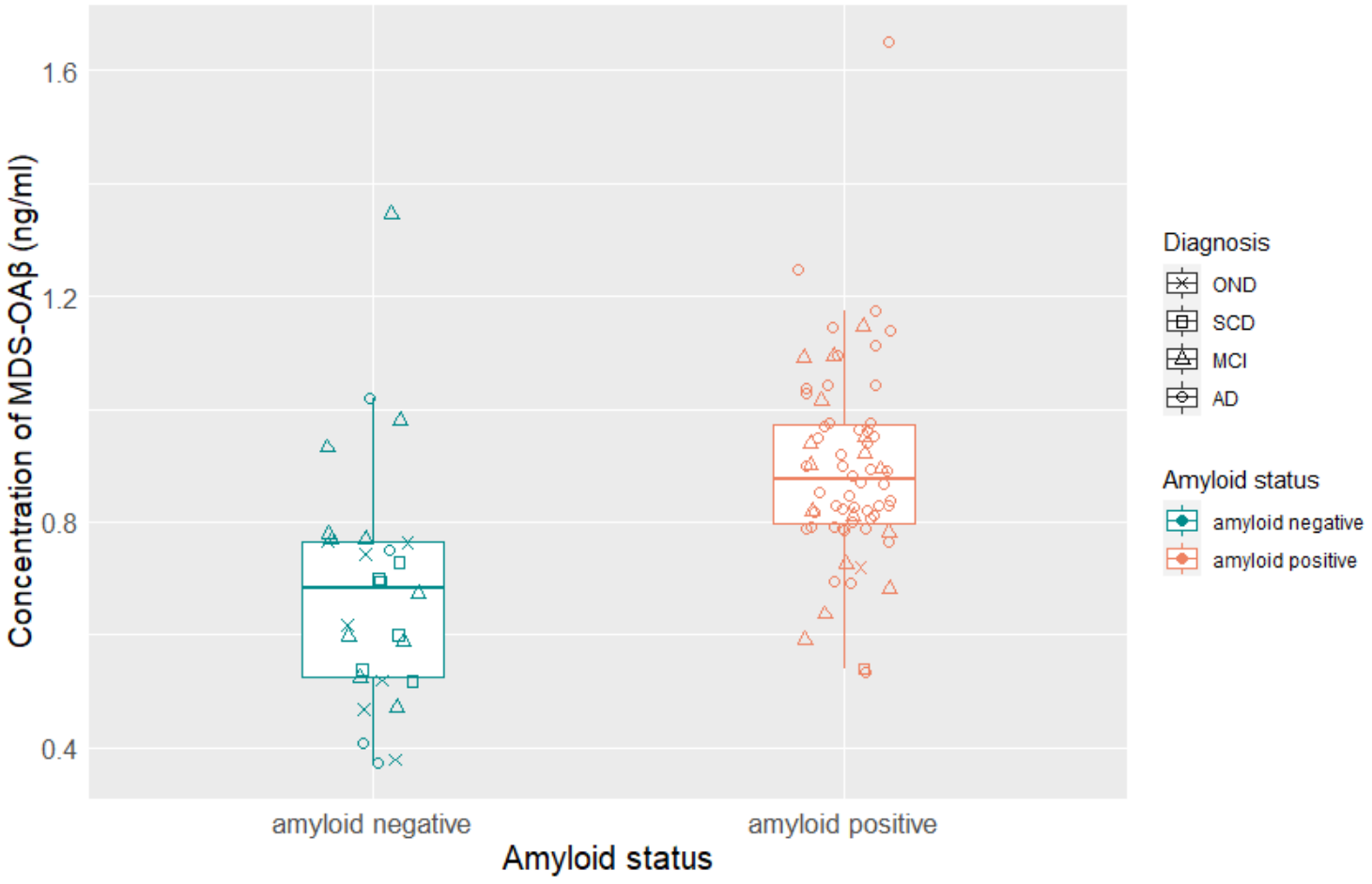

Figure 1

Concentration of plasma MDS-OAβ according to groups AD; Alzheimer's Disease, MCI; Mild Cognitive Impairment, MDS-OAβ; Multimer Detection System-Oligomeric Amyloid-β, OND; Other Neurodegenerative Disease, SCD; Subjective Cognitive Decline. MDS-OAβ as a predictor of amyloid status

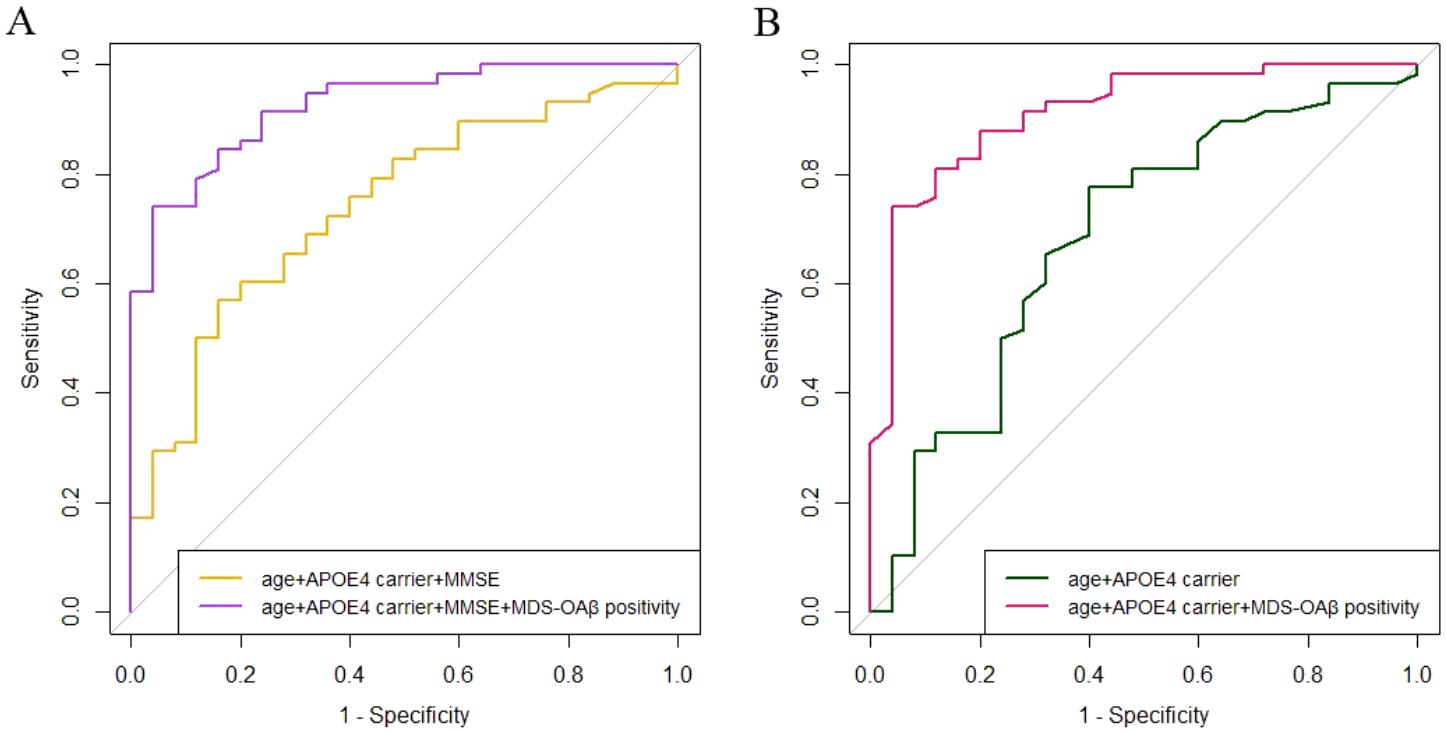

Figure 2

Receiver Operating Characteristic analysis of MDS-OAβ positivity with other predictors on amyloid PET positivity A. Added MDS-OAβ positivity to clinical information such as age, MMSE score, and APOE ε4 status, predictability for amyloid PET positivity improves. B. Considered only objective factors such as age and APOE ε4 status, combining with MDS-OAβ positivity strengthened the predictability on amyloid PET positivity MDS-OAβ; Multimer Detection System-Oligomeric Amyloid-β, MMSE; Mini-Mental-State-Examination.