

Validation of the Delirium Diagnostic Tool-Provisional (DDT-Pro) in a Skilled Nursing Facility and Comparison to the 4 'A's Test (4AT)

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Declaration of competing interest

Dr. Trzepacz and Dr. Franco are co-owners of the copyright for the Delirium Diagnostic Tool-Provisional, but do not charge a fee for not-for-profit use. No other co-authors have conflicts of interest to disclose.

Running title: DDT-Pro compared with 4AT for delirium detection in the skilled nursing

ABSTRACT

Objective: To validate the Delirium Diagnostic Tool (DDT-Pro) in a SNF and compare its performance to the 4 A's Test (4AT) in real life conditions.

Methods: Prospective cross-sectional study of 262 consecutively admitted adults to a SNF, independently assessed by psychiatrists using DSM-5 delirium criteria and by geriatricians using the DDT-Pro (0-9 points) and 4AT (0-12 points).

Results: 141 (53.8%) participants had dementia and 79 (30.1%) had delirium. DDT-Pro and 4AT were moderately correlated (-0.59). Accuracies against DSM-5 diagnosis ranged from 80 to 85% and were comparable between tools regardless of dementia. Recommended delirium cutoff for the DDT-Pro (≤ 6) had 77.2% sensitivity, 84% specificity, and NPV=89.5% and 4AT (≥ 4) had 54.4% sensitivity and 92.9% specificity, with lower specificity in the dementia subsample. DDT-Pro sensitivity increased (84.8%) at ≤ 7 cutoff. Sensitivity and specificity of all DDT-Pro and 2/4 4AT items displayed gradients along severity levels, but two dichotomously rated 4AT items had low positivity. The tools had low concordance ($p < 0.05$) for delirium positivity.

Conclusions: DDT-Pro is valid to detect delirium in SNF population where simple, structured tools with high sensitivity are needed. DDT-Pro items assess the three core domains of delirium as a continuous measure and may have advantages over the 4AT.

Keywords:

Delirium diagnosis

Psychiatric status rating scales

Geriatric assessment

Skilled nursing

Diagnostic tests comparison

1. Introduction

Delirium is a prevalent disorder in the skilled nursing facility (SNF) setting, 27% in one study using DSM-5 criteria [1]. Delirium is an impairment of consciousness caused by diverse medical-surgical conditions, especially in patients with preexisting dementia. Delirium has an acute/subacute onset and fluctuating course [2]. The delirium phenotype, using standardized assessment of a broad range of its symptoms, has identified three core symptom domains: Cognitive (attention/vigilance

plus other cognitive functions), Higher level thinking (language, thought process/comprehension) and Circadian (motor activity, sleep-wake cycle) [3–7]. Affective, perceptual and psychotic symptoms are much less common and considered noncore [6,8]. Discriminant analysis of Delirium Rating Scale-Revised-98 (DRS-R98) revealed three items that best discriminated delirium from both the MCI/dementia group (84.8%) and normal controls (92.8%) in an SNF population, where these items represented each of the three core domains [1].

Timely diagnosis of delirium in the SNF setting is important because it is associated with a poor prognosis. SNF patients with delirium are more than twice as likely to remain in the facility after 90 days, even after controlling for effects of depression, pain, and care needs [9]. Delirium in the SNF is associated with greater functional decline, 7% greater mortality during the stay [10], more transfers to the emergency room, and more acute care hospitalizations [11,12].

Unfortunately, delirium detection in SNFs is as low as 10% [13]. Reasons are related to health comorbidities, staff and SNF infrastructure. A high incidence of dementia complicates accurate differential diagnosis [10]. Because of advanced age of their patients, SNF staff assume cognitive deficits are attributable to dementia [14]. SNF staff are insufficiently cognizant of the mental status changes heralding delirium in patients with medical problems who are transferred to the SNF for acute rehabilitation following hospitalization [13,15]. SNFs are geared more toward rehabilitation therapies or residential care than to providing close medical attention to persons recently discharged from acute care hospitals given their lower nurse: patient ratio [16].

Moreover, the routine use of standardized tools for delirium detection in SNFs is uncommon, as is research on their performance characteristics.

The Delirium Diagnostic Tool-Provisional (DDT-Pro) is a brief scale designed to allow accurate delirium diagnosis by only assessing three symptoms, each representing one of the three core

domains of delirium [17]. It can provisionally diagnose delirium until an expert clinician can verify it. It also is a continuous quantitative measure of observable data with a high correlation for delirium severity (-0.913) to the DRS-R98 [17]. Its structured items enhance standardization for nonexpert raters. Under research conditions it is reliable and accurate for delirium diagnosis in a traumatic brain injury unit and internal medicine ward, even in patients with baseline cognitive dysfunction from another neurocognitive disorder [17–19]. Reported sensitivities range from 88%-100% and specificities from 85.3%-94.4% using DSM-IV or DSM-5 delirium diagnosis [17,18]. When compared to the Confusion Assessment Method Algorithm (CAM-A) screening tool, the DDT-Pro produced a higher proportion of true positive test results, and a higher proportion of true negative cases among patients with a negative test result (NPV) [18]. The DDT-Pro has not yet been validated in the SNF.

A more recent brief screening tool than the CAM-A is the 4 'A's Test (4AT) [20]. It assesses alertness and temporal course dichotomously, and attention and orientation on Likert scales. The 4AT was originally validated in geriatric medicine and rehabilitation units, with 89.7% sensitivity and 84.1% specificity [20]. In a study using random assignment to be rated by either the CAM-A or 4AT, the 4AT had a higher sensitivity of 76% (vs 40%) and a lower specificity of 94% (vs 100%) though patients were not rated by both tools so direct comparison was not possible [21]. A recent metaanalysis of the 4AT found pooled sensitivity and specificity both at 88% when considering acute medical or surgical inpatients, care home and the emergency department [22].

Our aim was to assess performance characteristics of the DDT-Pro in a SNF where there is a high dementia prevalence and compare its delirium detection performance with the 4AT in the same patients when administered by clinical staff geriatricians in real life conditions.

2. Methods

2.1. Study design, Ethics and Participants

All adults admitted to the SNF Centre Sociosanitari Monterols in Reus, Spain were assessed within the first 24-72 hours following admission on weekdays during the same 8-hour day shift. Patients were excluded if consent was denied, or they were in stupor or coma, or unable to speak Spanish or Catalan. The collection occurred over 18 months where vacation periods were excluded.

Patients with and without DSM-5 delirium were included, regardless of their dementia status. All assessors were independent, and the study tools (DDT-Pro and 4AT) were both administered by the geriatrician responsible for the patient at the same visit.

The Standards for Reporting of Diagnostic Accuracy (STARD) guideline [23] was followed for this cross-sectional, prospective validation approved by the corresponding ethics committee (at Hospital Sant Joan, Reus, Tarragona, Spain). Written informed consent was obtained from participants or their proxy if there was a dementia diagnosis registered in the clinical chart or if a psychiatrist determined there was cognitively impaired.

2.2. Instruments

The relevant demographic and clinical variables were collected using a standard method.

2.2.1. Charlson Comorbidity Index

The CCI is an index of the severity of medical severity status which has prognostic value. It assigns a 1, 2, 3, or 6-point value to a variety of clinical conditions (cardiovascular, cerebrovascular, dementia, respiratory, diabetes mellitus, kidney function, AIDS, cancer, peptic ulcer, connective tissue, and liver disease) while controlling for age. Scores of 0-1 indicates no comorbidity, 2 low comorbidity, and ≥ 3 high medical comorbidity [24].

2.2.2. Informant Questionnaire on Cognitive Decline in the Elderly (IQCODE)- Spanish version

The IQCODE contains 26 structured questions to ask family or caregivers for information about cognitive impairment and functioning during the previous five years. Its score range is 26-130. We used the validated Spanish version where dementia is likely with scores >85 [25].

2.2.3. *Diagnostic and Statistical Manual-5th Edition (DSM-5) -Diagnostic criteria for Delirium*

Each DSM-5 criterion was recorded as present (Yes) or absent (No) for each participant [26], and the raters had access to any source of information available (caregivers/family, charts, staff) besides direct clinical assessment. The time frame for rating was the previous 24 hours.

2.2.4. *Delirium Diagnosis Tool-Provisional (DDT-Pro)-Spanish version*

The DDT-Pro is a 3-item brief structured scale for provisional diagnosis of delirium by nonexpert clinicians [17]. It contains structured and quantitatively scored items for evaluating vigilance and comprehension taken from the Cognitive Test for Delirium (CTD) and assessed directly by patient performance [27] and the sleep-wake cycle disturbance item from the DRS-R98, assessed from the patient and any other source for the preceding 12-24 hours [28], whose score values were reversed to align with the point scoring of the CTD items. The three items reflect and represent the three core symptom domains of delirium (Cognitive, Higher order thinking, Circadian) [3–7] to enhance accuracy since only three symptoms are being rated. Each item is rated objectively using tests or anchored descriptors of observations. The scores range from 9 points (best performance) to 0 (worst performance). The recommended cutoff for delirium is a DDT-Pro score ≤ 6 (score range 0-9) [17,18]. The ≤ 7 score has been recommended for detection of subsyndromal delirium (SSD) [19]. As determined by neuropsychological experts, it has two equivalent forms, A and B, where the two CTD vigilance and comprehension items differ for avoiding a possible learning effect when performing repeated administration. Each item is scored from 0-3 points, with CTD items following scoring formulas. The validated Spanish version was used [18].

2.2.5. 4 'A's Test (4AT)- Spanish version

The 4AT is a brief screening tool designed for non-experts to screen for delirium in hospital settings [20]. It comprises four items: alertness, Abbreviated Mental Test-4 (AMT-4) [29], attention, and acute change or fluctuating course. Its score range is 0–12 points, where ≥ 4 suggests possible delirium. Item #1 alertness is scored dichotomously as 0 points if the patient is alert but not agitated or drowsy but easily rousable, and 4 points if abnormal in any other way including stupor or coma. Item #2 AMT-4 assesses knowing one's age, date of birth, and orientation to place and year (0-2 points). Item #3 assesses attention using months of the year backwards (range 0-2). Item #4 assesses the degree of possibility for acute change or fluctuation in mental status over the preceding 2 weeks (0-4 points) as rated dichotomously as either 0 or 4 points. The 4AT takes about 2 minutes to administer and does not require special training.

2.3. Procedures

All patients were independently evaluated using DSM-5 delirium criteria as the reference standard by one of three psychiatrists, according to their availability during study days. Before study start-up, these three together evaluated five patients using DSM-5 delirium criteria for standardization. Prior to study onset three staff geriatricians responsible for assessments reviewed the DDT-Pro and 4AT instructions and could ask the senior researcher any questions for clarification. There was no other training in order to maintain this as a real-world study. Since they were going to do a single DDT-Pro administration, all three were told to use the A form of the tool. The three geriatricians alternated the order of administration of the two tools as they evaluated consecutive patients. A follow-up question session was held 3 months into the study by a senior psychiatrist researcher.

A different researcher reviewed the facility registers for new admissions, administered informed consent and informed the rest of the team about patients meeting the study criteria. This same researcher undertook sociodemographic variables and admission diagnosis, fulfilled CCI, and administered IQCODE.

Participants were assessed by their attending geriatrician using the DDT-Pro and 4AT, while blinded to the delirium diagnosis.

2.4 Analysis

Analyses were for delirium and no delirium comparisons that could further specify dementia subgroup.

Analyses used SPSS 23.0, unless otherwise specified. Though not normally distributed, continuous variables are described by means \pm standard deviation (SD) for facilitating interpretation and their mean-ranks compared using Mann-Whitney U. Chi-squared or Fisher exact test are used for dichotomous variable comparisons.

Spearman's rho was used for correlational analysis between DDT-Pro and 4AT scores.

Non-parametric receiver operating characteristic (ROC) analysis was used for criterion validation of the tools against DSM-5 delirium status. We report percentage of patients correctly classified (accuracy), and sensitivity and specificity of the continuous DDT-Pro and 4AT scores ranges. The Hanley-McNeil test was employed for accuracy (i.e., area under the ROC curves or AUC) comparisons in Epidat 3.1.

Individual item sensitivity and specificity are reported and correspond to the coordinates of each item score in a ROC curve. Frequencies in the no delirium and DSM-5 delirium groups of normal or

negative scoring (i.e., 3 for the DDT-Pro and 0 for the 4AT), of item positivity (i.e., any score different from normal) and of more severe abnormality are also reported.

Accuracy, sensitivity, specificity, positive and negative predictive value (PPV, NPV) and positive and negative likelihood ratio (+LR, -LR) for DSM-5 delirium were calculated with crosstabs analysis in a spreadsheet, for the recommended ≤ 6 DDT-Pro and ≥ 4 4AT scale cutoffs for presence of delirium.

We used Cochran Q test to compare the concordance for delirium status classification between the two tools without reference standard, according to their previously published diagnostic cutoff scores.

3. Results

3.1. Sample characteristics

According to DSM-5 criteria, 79 (30.1%) of 262 patients had delirium (see Table 1). Dementia was present in 141 (53.8%) and its prevalence was significantly higher in the delirium group (73.4% vs 45.4%). Male sex was also significantly more common in delirium group.

3.2. Tool comparisons

Supplementary Figure 1 shows patient flow through the study including ratings. As compared to DSM-5 criteria, the DDT-Pro diagnosed more patients as delirious while the 4AT diagnosed fewer (n=90 vs. 56 whole sample; n=67 vs. 45 in the dementia subgroup).

Spearman's correlation between DDT-Pro and 4AT scores as administered by the same geriatrician (n=262) was -0.59, and in the dementia subgroup (n=141) was -0.51.

3.3. Test validity

Figure 1 displays AUC graphs from ROC analyses for the DDT-Pro and 4AT. Accuracies against DSM-5 diagnosis ranged from 80 to 85% and were comparable between tools and in the dementia subsample.

Sensitivity and specificity for DSM-5 delirium at different cutoff values are in Table 2. The recommended ≤ 6 cutoff for the DDT-Pro delirium diagnosis had 77.2% sensitivity and 84% specificity. These values and those for the ≤ 7 cutoff, as recommended for SSD, were the most balanced among DDT-Pro cutoffs. At ≤ 7 sensitivity rose to 84.8% with 71.0% specificity. Both had somewhat lower specificity in the dementia subgroup while sensitivity remained essentially the same.

The recommended ≥ 4 cutoff for the 4AT had 54.4% sensitivity and 92.9% specificity. Sensitivity of the 4AT remained under 60.0% in the dementia subgroup where specificity was also decreased. A ≥ 3 4AT cutoff displayed a more balanced performance than the recommended ≥ 4 cutoff, with 73.4% sensitivity and 82.2% specificity, though specificity decreased to 68.7% in the dementia subgroup.

Discriminant analysis of individual items (Table 3) shows that DDT-Pro items have gradients of ascending sensitivity values and decreasing specificity values across all items as item scores increased. Frequency of presence at each severity level compared between DSM-5 delirium and no delirium groups was statistically different for all DDT-Pro items, except for item #3 sleep-wake cycle score 0 in the dementia subgroup.

In contrast, the 4AT item #1 alertness and item #4 acute onset/fluctuation, which have very divergent dichotomous scoring options of 0 (normal) or 4 (abnormal), showed very low sensitivity values when present, and their frequency of positivity in delirium group was quite low (item #1=5.1%, item #4=30.5%). Items #2 AM4T and #3 attention reached much better sensitivity values

and their positivity were both >81%. Frequency of presence of any abnormality in 4AT items was significantly different between DSM-5 delirium and no delirium groups, except for #1 alertness within the dementia subgroup where there was no difference.

Accuracy of the DDT-Pro cutoff ≤ 6 and 4AT cutoff ≥ 4 is shown in Table 4. DDT-Pro accuracy for DSM-5 diagnosis was only slightly higher than that of 4AT (82.1% and 81.3%) in the whole sample. In the dementia subgroup DDT-Pro and 4AT accuracy was the same (75.2%).

Indicators measuring the likelihood of a person having or not having delirium if the tools were positive or negative for the disorder, respectively, are in accordance with indicators assessing internal properties of the instruments (sensitivity, specificity). DDT-Pro NPV values were 82.4% in the dementia subgroup and 89.5% in the whole sample, while PPV values were lower (67%). The 4AT NPV values were lower than the DDT-Pro, with PPV better than those of the DDT-Pro (75.6%-76.8%). The +LR values of 4AT were higher than those of the DDT-Pro (i.e., better) and -LR of DDT-Pro were lower than the 4AT (i.e., better) regardless of the clinical scenario.

3.4. Concordance analysis

Table 5 displays concordance analysis for presence or absence of delirium according to the recommended cutoffs for both tools. Overall concordance rates were statistically different ($p < 0.05$) with 76.3% concordance in the whole sample and 70.2% for the dementia subgroup. These tools were particularly discordant for cases classified as positive for delirium — when the 4AT was compared to the DDT-Pro (46.7% and 52.2% in the dementia subgroup), and somewhat higher when the DDT-Pro was compared to the 4AT (75.0% and 77.8% in the dementia subgroup).

4. Discussion

This is a real-world validation study of the DDT-Pro for DSM-5 delirium diagnosis in 262 newly admitted patients to a SNF with a high medical comorbidity prevalence (CCI mean ≈ 3) and baseline dementia (>50%). Previous DDT-Pro validation in a general hospital sample included some dementia patients but medical acuity was higher [18]. Additionally, we compared DDT-Pro performance to that of the 4AT when both tools were administered to the same patients. Our study design contrasts with that comparing the 4AT to the CAM-A where patients were randomized to be rated by only one of those tests [21], which is an appropriate design for a clinical trial but not for tools validation.

The previously reported DDT-Pro ≤ 6 cutoff performed well in this study against the independent DSM-5 delirium diagnosis made by a consultant psychiatrist, with 77.2% sensitivity and 84% specificity. In the presence of dementia its sensitivity (77.6%) and -LR were almost unaffected, in a sample where nearly three-quarters of those with delirium also had dementia. In this SNF population, the ≤ 7 cutoff could also be considered because it improved sensitivity from 77% to $\approx 85\%$ (more so in the dementia subsample), with an acceptable reduction of specificity (from 84% to 71%, fewer in the dementia subsample) but which implies more false positives. However, this ≤ 7 cutoff has been validated for detection of SSD [19] so that the greater false positive cases of DSM-5 delirium using the ≤ 7 threshold might be actually attributable to SSD cases that deserve clinical attention in the SNF population.

The solid performance of the DDT-Pro in this SNF sample with high prevalence of dementia and comorbid conditions might be explained by its intentional design based on years of phenomenological research to delineate the core delirium phenotype [3–8,30–32]. The DDT-Pro allows non-expert evaluators to briefly measure delirium's three core symptom domains in a highly structured fashion to enable a provisional diagnosis. Our results reflect untrained clinical geriatricians administering the tools.

These two tools do not measure the same construct where the 4AT focuses on attention/alertness and temporal course while the DDT-Pro assesses core domain symptoms: vigilance, comprehension and sleep-wake cycle. These tools were only moderately correlated (0.59) and, when using their previously recommended cutoffs for delirium, were discordant for classification of patients as delirious when compared with each other. The DDT-Pro ≤ 6 cutoff found more cases of delirium than DSM-5, while the 4AT ≥ 4 cutoff found fewer (Supplementary Figure 1). Further, the DDT-Pro requires assessment of the three core domains of delirium whereas DSM-5 does not. Global accuracy (AUC) of the DDT-Pro and 4AT for DSM-5 delirium were both very good and comparable regardless of dementia status.

The performance patterns of individual items in these tools for detection of delirium was not homogeneous. Each DDT-Pro item displayed a sensitivity-specificity gradient according to its severity score range and distinguished delirium when positive at any degree, regardless of the dementia status. 4AT items #2 AM4T and #3 attention showed a similar gradient pattern and presence of abnormality in delirium cases. However, the dichotomously scored 4AT items #1 alertness and #4 acute onset/fluctuation (0=normal, 4=abnormal) had very low positivity for those with delirium (n=4 and n=24, respectively, in the whole sample, and n=2 and n=16 for the dementia subgroup) and exhibited very low sensitivity with very high specificity when positive (Table 3). Even though highly specific, item #1 positivity did not differentiate delirium from dementia in the dementia subgroup, due to its very low frequency for being positive. The structure of these dichotomous items combined with characteristics of the SNF population might explain this undesirable performance.

In addition to this scoring, 4AT item #1 alertness is a complex item conflating motor activity with cortical arousal. It combines difficulty to rouse or sleepiness with agitation or hyperactivity, and does not define a threshold for stupor or coma (which should preclude a delirium diagnosis) or

hyperactivity [20]. This item is even harder to rate in the SNF setting where patients have high prevalence of comorbid medical conditions and dementia hindering the definition of positivity for this item.

4AT item #4 assesses acute change or fluctuating course in alertness, cognition, and psychotic symptoms (“paranoia” and hallucinations), during the last two weeks until the present [20].

Though acute/subacute onset and fluctuating course are two hallmarks of delirium, they are difficult to discern in the SNF where patients have high prevalence of baseline neurocognitive alterations (dementia) [1]. Additionally, delusions and hallucinations are uncommon in delirium and fairly common in Alzheimer’s dementia [8,33], which might explain the low sensitivity and positivity prevalence of this item.

The unbalanced performance of the 4AT in this SNF study, with low sensitivity (54.4% and 58.6% in the dementia subsample) and high specificity (92.9% and 86.7%) might be attributed to the performance of items #1 and #4. Interestingly, we found a more balanced performance using the ≥ 3 cutoff, which in practical terms implies the exclusion of items #1 and #4 (because their score is 0 or 4), which improved the 4AT’s screening performance (sensitivity 73.4% and 82.8%) though with a less desirable decline in specificity (68.7%) in the dementia subsample (vs 73.5% for the DDT-Pro). These findings of better performance without items # 1 or #4 are corroborated by another validation study in eight nursing homes and senior day care centers where the 4AT ≥ 4 cutoff had low sensitivity and high specificity (34.7% and 97.2%), but with ≥ 3 cutoff had more balanced performance (61.3% sensitivity, 92.8% specificity) and even better for the ≥ 2 cutoff (93.1% sensitivity, 84.2% specificity) [34]. The 4AT might perform better delirium screening in the SNF using only items #2 and #3, and lower cutoffs.

The 4AT ≥ 4 cutoff was more useful in a large study of emergency departments and acute medical wards (76% sensitivity and 94% specificity) where 85.5% of the sample did not have baseline dementia [21].

The mean of 7 years of education for the current cohort from Spain is intermediate between the means for our previous DDT-Pro validation studies (Colombian 5 years, U.S. 10 years) [17,18]. The reliable performance of the tool across all three validation studies suggests it is suitable for a range of education levels and different cultures. The DDT-Pro for provisional diagnosis of delirium in a diversity of countries will be assessed in a multisite study.

Limitations of this study include DSM-5 for delirium diagnosis made by three different clinicians which introduces some variability in the reference standard, though these were consultant psychiatrists at the SNF who standardized diagnoses before the study start-up and assessed each individual DSM-5 criterion in a systematized way with dichotomous yes/no options. Geriatricians were self-trained to use the tools to mimic real world care, though they could ask clarifying questions before and during the study.

Though geriatricians consecutively alternated the order of administration of the DDT-Pro and 4AT, the possibility of bias for knowing the result of the first tool could affect results of the second. However, the design of the tools minimizes this possibility because items are not subjectively rated and there is little overlap of the constructs tested. Two of three DDT-Pro and two of four 4AT items are objectively tested material unlikely to be affected by bias. The other items do not overlap in their content between the tools, and they use descriptive ratings for information that would have to be obtained from observers or clinical staff. Furthermore, the correlation between the scores was only in the 0.5 range and the cut-off point of the two was discordant for the delirium classification.

In conclusion, the DDT-Pro performed well in the SNF using the cutoff for delirium delineated in acute medical settings (≤ 6) but it might be extended to the ≤ 7 threshold in SNF settings to increase sensitivity and capture milder delirium cases. The DDT-Pro had moderate correlation and a nonsignificant Cochran Q test for concordance with the 4AT, especially relevant for positive cases, which could be attributable to the scoring structure of items on the 4AT, especially item #1 on which very few patients scored positively. Because the DDT-Pro assesses the three core domains of delirium unlike other brief delirium detection tools, such as the CAM-A and 4AT, it holds promise for distinguishing delirium in complicated SNF patients.

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Table 1. Demographic and clinical characteristics of 262 patients from a skilled nursing facility, with or without DSM-5 delirium. Statistical comparisons are between delirium and no delirium groups.

	Whole sample (n =262)	Delirium (n =79)	No delirium (n =183)
Continuous variables	Mean ± SD	Mean ± SD	Mean ± SD
Age (years) mean	77.11 ± 10.05	77.66 ± 11,319	76.88 ± 9.481
Education (years)	7.00 ± 4.22	7.54 ± 5.218	6.76 ± 3.704
Charlson Comorbidity Index	2.92 ± 2.38	2.96 ± 2.377	2.90 ± 2.392
Discrete variables	N (%)	N (%)	N (%)
Male sex	147 (56.1)	55 (69.6)*	92 (50.3)*
Dementia**	141 (53.8)	58 (73.4)*	83 (45.4)*
Five most frequent main admission diagnoses:			
Organ insufficiency	47 (17.9)	8 (10.1)*	39 (21.3)*
Systemic infection	45 (17.2)	15 (19.0)	30 (16.4)
Fracture	43 (16.4)	9 (11.4)	34 (18.6)
Cerebrovascular disease	11 (4.2)	6 (7.6)	5 (2.7)
Neoplasm	9 (3.4)	2 (2.5)	7 (3.8)

*p<0.05 for Chi-square

**According to Informant Questionnaire on Cognitive Decline in the Elderly (IQCODE) in most cases, except 26 (9.9%) diagnosed by history documented in the clinical chart or by clinical impression using all accessible sources, due to absence of family/informant for history during the period needed to fulfill the IQCODE.

Abbreviations: SD: standard deviation

Table 2. Sensitivity (Sens %) and specificity (Spec %) corresponding to the coordinates of the receiver operator curve (ROC) for the various DDT-Pro and 4AT cutoffs, for DSM-5 delirium reference standard, as administered by geriatricians in newly admitted patients from a skilled nursing facility. Lower scores on the DDT-Pro are more abnormal and higher scores on the 4-AT are more abnormal. Rows are shaded for recommended cutoff values for diagnosis of delirium ≤ 6 for the DDT-Pro and ≥ 4 for the 4AT.

	Whole Sample, n=262		Dementia Subgroup, n=141	
DDT-Pro score	Sens %	Spec %	Sens %	Spec %
0	8.9	99.5	10.3	98.8
1	13.9	97.8	15.5	96.4
2	27.8	97.8	31.0	96.4
3	39.2	96.2	41.4	92.8
4	54.4	93.4	58.6	86.7
5	70.9	88.5	72.4	78.3
6	77.2	84.2	77.6	73.5
7	84.8	71.0	86.2	62.7
8	89.9	48.6	87.9	33.7
9	100	0.0	100	0.0
4AT score	Sens %	Spec %	Sens %	Spec %
0	100	0.0	100	0.0
1	96.2	45.4	98.3	21.7
2	88.6	65.6	93.1	39.8
3	73.4	82.0	82.8	68.7
4	54.4	92.9	58.6	86.7
5	25.3	96.2	24.1	94.0
6	24.1	97.3	24.1	95.2
7	15.2	97.8	15.5	96.4
8	10.1	98.9	10.3	97.6
9	-	-	-	-
10	5.1	99.5	3.4	98.8
11	-	-	-	-
12	5.1	100	3.4	100

Table 3. Sensitivity (Sens %) and specificity (Spec %) corresponding to the coordinates of the receiver operator curve (ROC) for individual item scores on the DDT-Pro and 4AT, using DSM-5 delirium as the reference standard. Tools were administered by geriatricians to newly admitted inpatients in a skilled nursing facility. Higher scores on the DDT-Pro items are more normal (3 is normal) whereas higher scores on the 4AT items are more abnormal (0 is normal). Also, number (%) of patients for each item's rating levels are listed, with a separate row for presence of any abnormality termed as "positivity". These are compared for significance in the whole sample for No Delirium (n=183) and Delirium (n=79) and the dementia subgroup for No delirium (n=83) and Delirium (n=58).

	Whole Sample (n=262)			Dementia Subgroup (n=141)		
	Sens % / Spec %	No Delirium n=183	Delirium n=79	Sens % / Spec %	No Delirium n=83	Delirium n=58
DDT-Pro items & scores		n (%)	n (%)		n (%)	n (%)
1. Comprehension						
Positivity		58 (31.7)	58 (73.4)*		36 (43.4)	44 (75.9)*
0	30.4 / 97.3	5 (2,7)	24 (30.4)*	32.8 / 5.2	4 (4.8)	19 (32.8)*
1	46.8 / 94.0	11 (6.0)	37 (46.8)*	50.0 / 90.4	8 (9.6)	29 (50.0)*
2	73.4 / 68.3	58 (31.7)	58 (73.4)*	75.9 / 56.6	36 (43.4)	44 (75.9)*
3	100 / 0.0	125 (68.3)	21 (26.6)*	100 / 0.0	47 (56.6)	14 (24.1)*
2. Vigilance						
Positivity		42 (23.0)	61 (77.2)*		31 (37.3)	45 (77.6)*
0	72.2 / 89.1	20 (10.9)	57 (72.2)*	74.1 / 80.7	16 (19.3)	43 (74.1)*
1	73.4 / 86.9	24 (13.1)	58 (73.4)*	75.9 / 78.3	18 (21.7)	44 (75.9)*
2	77.2 / 77.0	42 (23.0)	61 (77.2)*	77.6 / 62.7	31 (37.3)	45 (77.6)*
3	100 / 0.0	141 (77.0)	18 (22.8)*	100 / 0.0	52 (62.7)	13 (22.4)*
3. Sleep-wake cycle						
Positivity		48 (26.2)	48 (60.8)*		25 (30.1)	34 (58.6)*
0	10.1 / 96.2	7 (3.8)	8 (10.1)*	12.1 / 94.0	5 (6.0)	7 (12.1)
1	22.8 / 94.5	10 (5.5)	18 (22.8)*	24.1 / 91.6	7 (8.4)	14 (24.1)*
2	60.8 / 73.8	48 (26.2)	48 (60.8)*	58.6 / 69.9	25 (30.1)	34 (58.6)*
3	100 / 0.0	135 (73.8)	31 (39.2)*	100 / 0.0	58 (69.9)	24 (41.4)*
4AT items & scores		n (%)	n (%)		n (%)	n (%)
1. Alertness						
Positivity		1 (0.5)	4 (5.1)*		1 (1.2)	2 (3.4)
0	100 / 0.0	182 (99.5)	75 (94.9)*	100 / 0.0	82 (98.8)	56 (96.6)
4	5.1 / 99.5	1 (0.5)	4 (5.1)*	3.4 / 98.8	1 (1.2)	2 (3.4)
2. AM4T						
Positivity		78 (42.6)	70 (88.6)*		55 (66.3)	54 (93.1)*
0	100 / 0.0	105 (57.4)	9 (11.4)*	100 / 0.0	28 (33.7)	4 (6.9)*
1	88.6 / 57.4	78 (42.6)	70 (88.6)*	93.1 / 33.7	55 (66.3)	54 (93.1)*
2	59.5 / 83.1	31 (16.9)	47 (59.5)*	70.7 / 71.1	24 (28.9)	41 (70.7)*
3. Attention						
Positivity		78 (42.6)	64 (81.0)*		56 (67.5)	51 (87.9)*

0	100 / 0.0	105 (57.4)	15 (19.0)*	100 / 0.0	27 (32.5)	7 (12.1)*
1	81.0 / 57.4	78 (42.6)	64 (81.0)*	87.9 / 32.5	56 (67.5)	51 (87.9)*
2	36.7 / 94.0	11 (6.0)	29 (36.7)*	44.8 / 88.0	10 (12.0)	26 (44.8)*
4. Acute/fluctuation						
Positivity		7 (3.8)	24 (30.4)*		5 (6.0)	16 (27.6)*
0	100 / 0.0	176 (96.2)	55 (69.6)*	100 / 0.0	78 (94.0)	42 (72.4)*
4	30.4 / 96.2	7 (3.8)	24 (30.4)*	27.6 / 94.0	5 (6.0)	16 (27.6)*

*p<0.05 for Chi-squared or Fisher's Exact test comparison within each item between No delirium and Delirium

Abbreviations: AM4T: Abbreviated Mental Test

Table 4. Accuracy of the DDT-Pro and 4AT according to DSM-5 criteria reference standard when administered by geriatricians to newly admitted patients in a skilled nursing facility using previously published suggested delirium cutoff scores of ≤ 6 for DDT-Pro and ≥ 4 for 4AT. Accuracy, sensitivity, specificity, and positive and negative predictive values are in percentages. Positive and negative likelihood ratios are reported.

	Accuracy	Sensitivity	Specificity	PPV	NPV	+LR	-LR
	% (95% CI)	% (95% CI)	% (95% CI)	% (95% CI)	% (95% CI)	LR (95% CI)	LR (95% CI)
DDT-Pro cutoff ≤ 6							
Whole sample, n=262	82.1 (76.8-86.4)	77.2 (66.2-85.6)	84.2 (77.9-89.0)	67.8 (57.0-77.0)	89.5 (83.7-93.5)	4.87 (3.42-6.95)	0.27 (0.18-0.41)
Dementia subgroup, n=141	75.2 (67.1-81.9)	77.6 (64.4-87.1)	73.5 (62.5-82.3)	67.2 (54.5-77.9)	82.4 (71.5-90.0)	2.93 (1.99-4.30)	0.30 (0.19-0.50)
4AT cutoff ≥ 4							
Whole sample, n=262	81.3 (75.93-85.7)	54.4 (42.9-65.5)	92.9 (87.9-96.0)	76.8 (63.3-86.6)	82.5 (76.5-87.3)	7.66 (4.37-13.43)	0.49 (0.38-0.63)
Dementia subgroup, n=141	75.2 (67.1-81.9)	58.6 (45.0-71.1)	86.7 (77.1-92.9)	75.6 (60.1-86.6)	75.0 (64.9-83.0)	4.42 (2.45-7.99)	0.48 (0.35-0.66)

Abbreviations: PPV: positive predictive value. NPV: negative predictive value. +LR: positive likelihood ratio. -LR: negative likelihood ratio. 95% CI: 95% confidence interval.

Table 5. Concordance analysis between the DDT-Pro and the 4AT using their corresponding ≤ 6 and ≥ 4 cutoffs for delirium diagnosis in newly admitted patients to a skilled nursing facility who were assessed by geriatricians. Concordance comparisons with Cochran Q are within each one of the two crosstabs. Both whole sample and dementia subgroup comparisons were statistically discordant ($p < 0.05$).

Concordance Analysis	Crosstabs Values			
Whole sample, n=262	DDT-Pro ≤ 6			
4AT ≥ 4	Negative n	Positive n	Total n	Concordance with 4AT
Negative n	158	48	206	76.7%*
Positive n	14	42	56	75.0%**
Total n	172	90	N=262	
Concordance with DDT-Pro	91.9%*	46.7%**		76.3%***
Dementia subgroup, n=141	DDT-Pro ≤ 6			
4AT ≥ 4	Negative n	Positive n	Total n	Concordance with 4AT
Negative n	64	32	96	66.7%*
Positive n	10	35	45	77.8%**
Total n	74	67	N=141	
Concordance with DDT-Pro	86.5%*	52.2%**		70.2%***

* Concordance for classification as negative for delirium.

** Concordance for classification as positive for delirium.

*** Overall concordance (concordance n for negatives + concordance n for positives / N x 100).

Legend for Figure 1

Figure 1. Area under the receiver operator characteristics (ROC) curves (AUC) for diagnosis of delirium by DSM-5 criteria: the DDT-Pro is on the left and 4AT on the right. Both tools were administered by the same geriatrician to consecutively admitted patient in a skilled nursing facility. The top row is for the whole sample and the bottom row is for the dementia subgroup. DSM-5 delirium diagnostic criteria are the reference standard, and all AUC are comparable according to Hanley-McNeil test ($p>0.05$).