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Alterations in Functional Brain Activity as Predictors of Suicide Risk in Late-Life Depression: A Systematic Review

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Abstract

Introduction: Late-life depression (LLD) is a significant risk factor for suicide in older adults, yet clinical assessments for suicidality are often limited by subjective reporting and lack of predictive validity. Functional neuroimaging has highlighted overlapping alterations in neurocircuitry underlying emotional processing, decision-making and cognitive control between LLD and suicidality, potentially serving as predictors of suicide risk. However, no review to date has synthesized this evidence in the context of LLD.

Methods: A systematic search was conducted in Ovid MEDLINE, Embase and APA PsycInfo databases, following PRISMA guidelines. Eligible studies included older adults (≥55 years) with clinically defined LLD, validated measures of suicidality, and fMRI data. Of 1829 articles identified, eight studies met the inclusion criteria. Study quality was assessed using the Newcastle-Ottawa Quality Assessment Scale.

Results: Functional alterations were observed in frontostriatal and limbic circuits. Resting-state studies reported disrupted connectivity within/between the dorsolateral prefrontal cortex (DLPFC), ventrolateral prefrontal cortex (VLPFC), orbitofrontal cortex (OFC), caudate nucleus, and amygdala. Task-based studies revealed blunted ventromedial prefrontal responses to reward and heightened frontal operculum activation during socioemotional tasks among suicide attempters compared to depressed non-suicidal and healthy individuals.

Discussion: Disruptions in functional brain activity in LLD that contribute to suicide risk may reflect impaired decision-making, reward valuation, cognitive control, and affective dysregulation. Differences in functional activation and connectivity may distinguish suicidal ideation from suicide attempts, though further studies with larger, more diverse samples and longitudinal designs are needed to clarify this.

Conclusion: Functional neuroimaging reveals convergent patterns of dysregulation in key brain networks associated with suicide risk in LLD. These findings highlight the potential for imaging-informed models of suicide risk stratification and targeted neuromodulation. Longitudinal and interventional studies are needed to refine predictive biomarkers and improve clinical utility.

Keywords: depression; functional neuroimaging; functional connectivity; suicide risk

Introduction

Older adults face a disproportionately elevated suicide risk compared to other age groups. In 2021, the global annual death rate by suicide among individuals aged over 65 years was 27.3 per 100,000, compared to 11.6 per 100,000 in the general population [1]. This elevated risk is shaped by factors including social isolation, co-morbid physical illness, perceived burdensomeness and psychiatric disorders [2, 3], with higher suicide rates among males (12.3 per 100,000) than females (5.6 per 100,000) [4]. Late-life depression (LLD) is the most common psychiatric diagnosis among elderly suicide victims, with 63% having depression at the time of death [5]. LLD is characterised by somatic complaints, cognitive changes, and loss of interest, and is a major risk factor for suicide [6]. Suicide attempts in older adults are characterised by higher levels of intent and more extensive planning than those observed in younger individuals [7]. In primary care settings, the emergence of suicidal ideation is closely tied to the course of depression and most commonly observed in conjunction with depressive symptoms [8]. Importantly, older adults are more likely to have contact with primary care providers within one month of completed suicide compared to younger adults [9], highlighting a crucial window for the identification and management of suicide risk in this vulnerable group.

However, clinicians and common suicide risk assessment tools are limited in their ability to accurately predict future suicide attempts or deaths, with low positive

predictive value and a lack of standardized, prospectively validated instruments [10, 11]. Traditional screening methods involve structured clinical interviews and questionnaires, which predominantly rely on self-report measures and may be subject to biases stemming from social stigma, fear of negative consequences, and confidentiality concerns [12]. Many patients are resistant to expressing suicidal ideation when asked by clinicians [13, 14], and older adults are less likely to verbalize suicidal thoughts than younger individuals [7], further complicating the evaluation of suicide risk. This has motivated the search for more objective biological markers to complement clinical assessments in predicting suicide risk.

The integration of functional imaging data has emerged as a promising approach, as neuroimaging studies have reported alterations in functional connectivity within and between large-scale brain networks in individuals affected by LLD. Resting-state fMRI studies have highlighted disrupted connectivity within the default mode network (DMN), executive control network and cognitive control network [15–17]. Increased connectivity within the DMN may reflect heightened rumination and self-referential processing; these have been consistently observed in individuals with Major Depressive Disorder (MDD) [18], supporting their relevance to depressive symptomatology. Reduced connectivity in control networks could indicate executive dysfunction and impaired emotion regulation, which are also prominent features in MDD. Furthermore, these brain activity changes show considerable overlap with those implicated in suicidality, involving the cognitive control network (CCN), DMN and salience and emotion network (SEN) [19] as well as the orbitofrontal cortex (OFC) and dorsomedial prefrontal cortex [20]. These regions are associated with impaired reward processing and decision-making observed in suicide attempters, highlighting neural mechanisms that may contribute to increased suicide risk. Together, these findings demonstrate the role of altered functional connectivity in the pathophysiology of late-life depression and its associated suicide risk.

In addition, task-based fMRI paradigms provide complementary evidence by directly probing neural circuits relevant to depression and suicidality, offering more process-specific insights. A meta-analysis of seven task-fMRI studies found that MDD patients with a history of suicide attempts (SA) showed altered activation in the left insula and bilateral fusiform gyrus during emotional and cognitive tasks compared to non-suicidal MDD patients, suggesting that dysfunctions in emotion regulation, negative information processing, and self-awareness may be associated with suicide risk [21]. Other studies have found alterations in fusiform gyrus activity during emotional face processing [22], while DMN and basal ganglia activity have been implicated through facial expression and verbal-emotion pairing tasks [23]. These findings point to aberrant neural activity within networks subserving cognitive control and emotional processing.

While neuroimaging findings in MDD have been the focus of multiple recent reviews [24–27], functional alterations underlying LLD may show distinct features compared to younger populations due to age-related changes in brain structure and function [28–31], emphasizing the need for LLD-specific investigations.

Collectively, these developments highlight the potential of neuroimaging approaches to advance our neurobiological understanding of suicide risk and improve clinical approaches seeking to reduce suicidal ideation in LLD. To date, however, no review has systematically synthesized the evidence on alterations in functional brain activity as predictors of suicide risk in LLD. Given the complex interplay between LLD and suicide risk and the emerging evidence for distinct neurobiological signatures underlying suicidality, a comprehensive appraisal of this literature is both timely and necessary.

Methods

Following PRISMA guidelines, a comprehensive literature search was conducted in Embase, MEDLINE, and APA PsycInfo databases in June 2025. The objective was to identify studies examining functional brain alterations associated with suicide risk in older adults with late-life depression (LLD).

The search strategy was built from three concepts:

1. Late life: “late life” OR late-life OR geriatric OR elderly OR aged OR "old age" OR older
2. Depression: depress* OR "major depress*"
3. Suicide: suicid* OR exp Suicide

The three concepts were combined using the AND operator and executed with adjacency operators *adj3* and field tags *.tw,kf.* in Ovid across all three databases. No restrictions on publication date or study location were applied.

Inclusion criteria were as follows: (1) case-control or observational study design (cross-sectional or longitudinal); (2) participants aged ≥55 years with a clinically defined late-life depression which includes current measure(s) or characterisation of depressive symptoms; (3) suicidality assessed using validated instruments, including suicidal ideation, plans, or history of SA; (4) use of resting-state or task-based functional magnetic resonance imaging (fMRI) to assess functional activity or connectivity.

Articles were excluded if they met any of the following criteria: (1) case reports, meta-analyses, systematic reviews, scoping reviews, conference abstracts, or theoretical commentaries; (2) clinical or intervention trial; (3) studies that did not use functional MRI (e.g. EEG, PET, MEG, post-mortem studies); (4) inclusion of populations with primary diagnoses of psychosis, substance use disorder (within the past 12 months), Parkinson’s disease, Alzheimer’s disease, or any other neurodegenerative or neurological disorder that could independently affect brain

structure or function; and (5) studies that did not report suicide-related outcomes or focused exclusively on non-depressed or non-older adult populations.

Study selection and data extraction were carried out by a single reviewer (LL). Titles and abstracts were initially screened for relevance, followed by full-text review based on the eligibility criteria. Extracted variables included study design, participant demographics, diagnostic and clinical assessment tools, imaging modality and analysis pipeline, task paradigms as well as functional brain alterations associated with suicidality as the primary outcome. Forward and reverse citation searching for included studies was conducted using Scopus.

Articles were organised based on the type of neuroimaging analysis (resting-state or task-based) and a narrative synthesis was conducted. Study quality was assessed using the Newcastle-Ottawa Quality Assessment Scale adapted for cross-sectional studies [32].

Results

The initial search yielded a total of 1829 articles after duplicates were removed. Following single-reviewer title and abstract screening, 53 studies were screened for full-text review, of which 7 met the eligibility criteria. Forward and reverse citation tracking of the included studies further yielded 10 additional studies for full-text screening, where 9 studies were excluded, leaving 8 studies included in the present review (Table 1). The search process and study selection are documented in a PRISMA 2020 flow diagram (Figure 1).

Table 1. Summary of Studies Included in Review

Author, Year	Study Population	Mean Age (SD)	% Female	Characterisation of LLD	Suicidality Measure(s)	Type of fMRI Analysis	Functional Connectivity Findings
Chen 2024 [34]	32 SI, 76 N-S LLD, 75 HC	67.67 (7.36); 67.64 (7.00); 66.83 (5.86)	86.27; 75.00; 68.00	DSM-IV criteria; HAMD-17	Current SI (questionnaire)	Seed-based, sliding window	rHab-lOFC dynamic FC linked to visuospatial skills in suicidal ideation.
Lin 2024 [29]	48 suicidal (SA/SI), 35 N-S LLD	65.0 (4.8); 67.2 (5.8)	83.33; 80.00	DSM-5 criteria; HAMD-17	BSS, MINI	3D CNN, cross-sample entropy	DMN/FPN/CON regions (most reliably right amygdala, left caudate) predicted suicidality (SA/SI).
Lin 2023 [35]	32 SI, 41 N-S LLD, 54 HC	67.91 (7.34); 68.00 (6.97); 67.70 (5.28)	90.63; 78.05; 66.67	DSM-IV criteria; HAMD-17*	Suicide questionnaire	Seed-based	↓ DLPFC connectivity with angular gyrus/precuneus in SI group.
Gao 2023 [30]	24 SA, 30 SI, 37 N-S LLD	64.60 (4.79); 67.13 (5.98); 67.97 (5.83)	96.67; 83.33; 81.32	DSM-5 criteria; MINI	Chinese BSS, SPS, TSII, MINI	CPM, graph theory	Negative FC network (somatosensory /orbitofrontal) linked to number of attempts.
Shao 2022 [31]	35 SA, 33 SI, 45 N-S LLD	64.74 (5.22); 67.48 (5.64); 67.73 (5.68)	94.29; 81.82; 71.11	DSM-5 criteria; HAMD-17	BSS, TSII, SAD PERSONS	Seed-based, spectral DCM	Negative VLPFC/OFC-caudate rsFC in non-suicidal; positive in suicidal groups.
Hsu 2025 [33]	24 SA, 37 SI, 42 N-S LLD	64.25 (0.94); 67.32 (0.77); 66.86 (0.83)	91.67; 83.78; 73.8	DSM-5 criteria; HAMD-17	MINI (lifetime ideation/ attempts)	Seed-based	Bilateral DLPFC activation in all subgroups; VLPFC in non-suicidal/SI groups.

Author, Year	Study Population	Mean Age (SD)	% Female	Characterisation of LLD	Suicidality Measure(s)	Type of fMRI Analysis	Functional Connectivity Findings
Vanyukov 2015 [36]	18 SA, 13 N-S LLD, 18 HC	67.44 (7.0); 68.15 (6.1); 70.05 (7.7)	33; 69; 60	SCID/DSM-IV criteria; HAMD-17*	BSS, SIS	Voxel-wise regression	Frontal operculum hyperactivation to angry faces in poorly planned attempts.
Dombrovski 2013 [32]	15 SA, 18 N-S LLD, 20 HC	65.9 (6.3); 66.7 (5.7); 70.7 (8.7)	47; 67; 60	SCID/DSM-IV criteria; HAMD-17	BSS, SIS	Voxel-wise regression	Blunted vmPFC reward signals in suicidal group.

LLD: Late-Life Depression; MDD: Major Depressive Disorder; DSM-5/DSM-IV: Diagnostic and Statistical Manual of Mental Disorders, 5th/4th Edition; HAMD-17: 17-item Hamilton Depression Rating Scale; MINI: Mini-International Neuropsychiatric Interview; SCID: Structured Clinical Interview for DSM Disorders; DLPFC: dorsolateral prefrontal cortex; VLPFC: ventrolateral prefrontal cortex; rHab: right habenula; lOFC: left orbitofrontal cortex; FC: functional connectivity; rsFC: resting-state functional connectivity; DCM: Dynamic Causal Modelling; CPM: Connectome-based Predictive Modelling; DMN: Default Mode Network; FPN: Frontoparietal Network; CON: Cingulo-Opercular Network; BSS: Beck Scale for Suicidal Ideation; SPS: Suicide Probability Scale; TSII: Triggers of Suicide Ideation Inventory; SIS: Beck Suicide Intent Scale; N-S: non-suicidal; HC: healthy (non-depressed) controls; SI: suicidal ideation/plan; SA: suicide attempt; fMRI: functional Magnetic Resonance Imaging; DTI: Diffusion Tensor Imaging; CNN: Convolutional Neural Network. *excluded suicide item

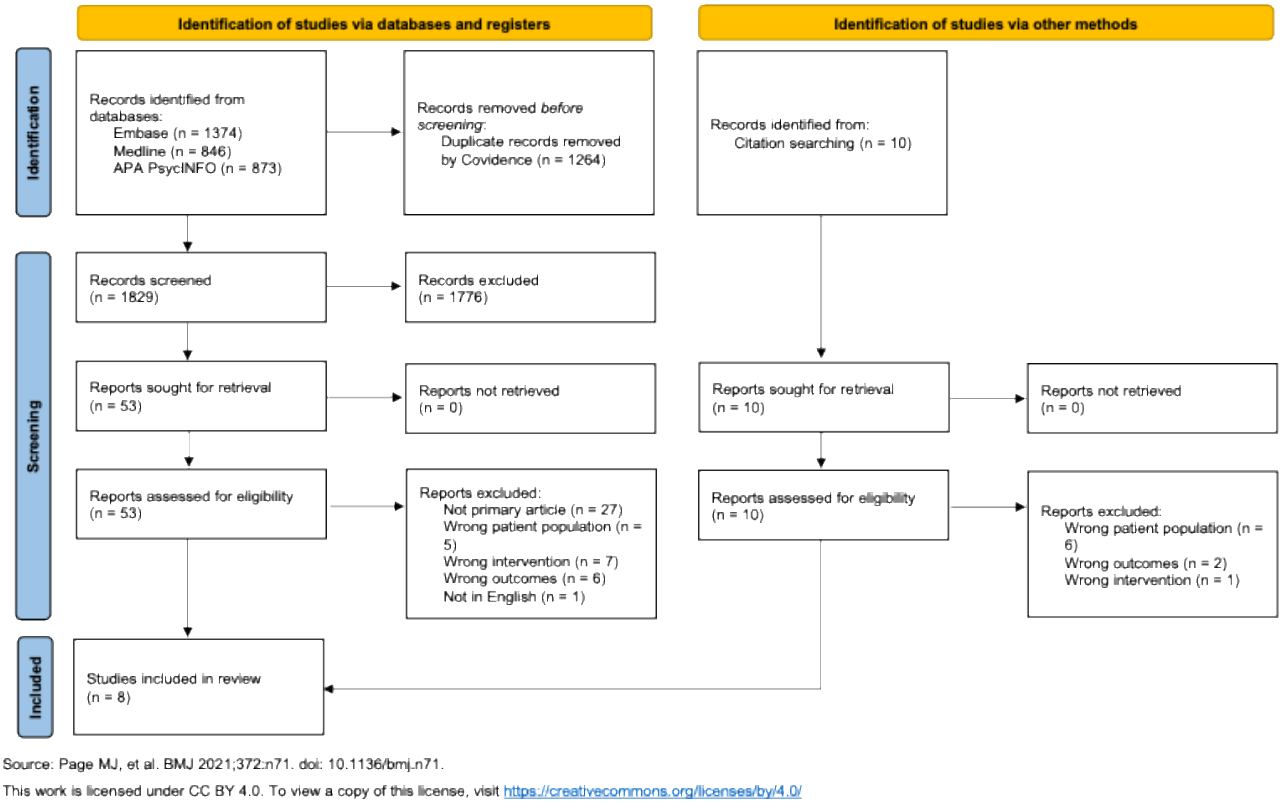

Figure 1. PRISMA 2020 Flow Diagram of the Present Systematic Review

All eight studies used the DSM-5 or DSM-IV as the diagnostic criteria for LLD. Depression severity was primarily assessed using the Hamilton Depression Rating Scale (HAMD-17), while suicidality measures included the Beck Scale for Suicide Ideation (BSS) (50% studies [33–36]), Mini-International Neuropsychiatric Interview (MINI) (37.5% [33, 34, 37]), and questionnaires (25% [38, 39]). Cognitive screening and exclusion of subjects was universally performed using the Mini-Mental State Examination (MMSE), with two studies incorporating additional neuropsychological batteries [38, 39]. Patient groups included some combination of non-suicidal (N-S) individuals with LLD, healthy non-depressed controls (HC), individuals with a history of suicide attempt (SA), and individuals with current or past suicidal ideation or plans (SI). Patient groups had mean ages ranging from 64.6 to 70.7 years. Females accounted for 33-96.67% of LLD patients, representing the majority in all but one subgroup (SA) in two studies [36, 40]. Five studies used resting-state fMRI [33–35, 38, 39], with one incorporating diffusion tensor imaging [34], while three employed task-based paradigms: two using emotional/executive function tasks [37, 40] and one using a reward learning task [36]. Several studies also employed machine learning algorithms which used neuroimaging features together with suicidality questionnaire scores [34] and the subgroup (N-S, SI, SA) of the patient [33] to improve classification accuracy and thus prediction of suicidality. Additional study characteristics, including clinical and cognitive information of the participants, are provided in Supplementary Table 1.

Resting-State FMRI Findings

Patterns of altered prefrontal activity were consistently observed in the 5 studies which employed resting-state fMRI. SI individuals showed reduced resting-state functional connectivity (rsFC) between the dorsolateral prefrontal cortex (DLPFC) and parietal regions (angular gyrus, precuneus) compared to NS and HC [39]. N-S individuals exhibited significantly negative rsFC between the ventrolateral prefrontal cortex (VLPFC)/OFC and bilateral caudate, but this pattern was absent in both SI and SA subgroups. In dynamic causal modelling analysis, VLPFC/OFC-to-caudate connectivity was also significantly negative in NS but not SA, while caudate-to-VLPFC/OFC connectivity was marginally positive in SI [35]. SI also moderated the association between right habenula-left OFC dynamic FC and visuospatial skills [38].

At the network level, Gao et al. [34] used connectome-based predictive modelling to identify distinct FC profiles between SA, SI and HC groups, implicating the OFC, cingulate cortex and inferior temporal gyrus, as well as somatosensory processing regions: the primary somatosensory cortex, fusiform gyrus and cerebellum. Lin et al. [33] identified the DMN, fronto-parietal network and cingulo-opercular network, as well as the right rolandic operculum, right amygdala, right inferior occipital gyrus, temporal poles in the right superior temporal gyrus, and left middle temporal gyrus. The right amygdala and left caudate were highlighted as the most reliable nodes to classify suicidality (SA/SI), obtaining >75% accuracy across all six cross-validation processes.

Task-Based FMRI Findings

Despite differences in task paradigms, the three included studies linked suicidality with dysfunctional neural processing in the prefrontal cortex.

Using a reward learning task, Dombrovski et al. [36] found that SA was associated with weaker response to expected reward in the pericallosal ventromedial prefrontal cortex (VMPFC), even after controlling for depression group status. The blunted modulation of paralimbic structures by expected rewards was further related to poor attempt planning within the SA group.

Vanyukov et al. [40] studied the processing of socioemotional stimuli using the faces and shapes task. Among SA individuals, increased activity in the right frontal operculum in response to angry faces was associated with poor attempt planning.

In a numerical Stroop task [37], all subgroups experienced robust activation in the bilateral DLPFC, but bilateral VLPFC only in NS and SI (not SA); this remained after controlling for LLD duration. The face/shape matching task was less reliable, showing DLPFC activation only in NS and SA under the face condition, and only in SI when contrasting the face and shape conditions, with significant activation limited to NS after adjusting for covariates. VLPFC activation was not significant in any subgroup with this task. Notably, SI showed a higher success rate than NS with the face/shape task, while SA showed higher success with the Stroop task.

Quality Assessment

Most studies were of good quality, with an average score of 7.625 out of 10 (Table 2). All studies controlled for confounding variables such as age, sex, education, LLD duration, lifetime substance use and antidepressant exposure except for one study which did not report whether demographic or clinical covariates were controlled for or whether appropriate statistical tests were conducted [33]. Only one study provided a justification of the sample size through power analysis [34].

Table 2. Quality Assessment Results Using the Newcastle-Ottawa Scale Adapted for Cross-Sectional Studies

Author, Year	Representative Sample	Sample Size	Non-Respondents	Ascertainment of Exposure	Comparability	Assessment of Outcome	Statistical Test	Total
Chen 2024 [34]	*			*	**	**	*	8
Lin 2024 [29]	*			**	*	**		6
Lin 2023 [35]	*			*	**	**	*	7
Gao 2023 [30]	*	*		**	**	**	*	9
Shao 2022 [31]	*			**	**	**	*	8
Hsu 2025 [33]	*			*	**	**	*	7
Vanyukov 2015 [36]	*			**	**	**	*	8
Dombrovski 2013 [32]	*			**	**	**	*	8

Discussion

This review identified convergent patterns of altered functional brain activity associated with suicide risk in late-life depression (LLD). Across both resting-state and task-based fMRI studies, prefrontal regions, including the DLPFC, VLPFC, and OFC, as well as the caudate, amygdala, and parietal regions, emerged as key nodes differentiating suicidal from non-suicidal subgroups.

Altered connectivity within prefrontal-subcortical circuits was consistently observed across the reviewed studies, including regions of the cingulate, striatum and amygdala. In particular, non-suicidal and suicidal LLD individuals showed distinct rsFC patterns between the VLPFC/OFC and bilateral caudate nucleus, differing in both strength and directionality [35]. The moderation of the relationship between habenula–OFC connectivity and visuospatial skills by SI also suggests possible interaction between limbic and cognitive circuits in suicide risk [38]. OFC and caudate circuits are important for reward-based reinforcement learning and goal-directed behaviours [41–43], while the habenula has been implicated in negative reward prediction and aversive states [44]. These neural deficits are thought to underlie the motivational and affective impairments seen in anhedonia, which is associated with SI independent of depression [45, 46]. Furthermore, these findings align with structural connectivity studies linking SA to structural abnormalities in fronto-striato-limbic pathways [47–49], supporting the idea that dysregulated reward valuation may underlie suicidal vulnerability in LLD.

These findings are reinforced by the task-based studies, where a blunting of VMPFC responses is seen in response to expected rewards [36]. This may reflect disrupted reward computations which undermine one's ability to evaluate future outcomes [50], leading to more maladaptive decision-making and poorly planned SA. Given the extensive evidence linking suicidal acts to impairments in cognitive control and value-based decision-making [51], this blunting of reward circuitry responses is consistent with neuropsychological findings.

Additionally, while reliable DLPFC activation was seen during cognitive interference (Stroop task) across LLD subgroups, VLPFC recruitment was attenuated in suicide attempters, suggesting weakened inhibitory control or affective modulation [37]. This aligns with functional near-infrared spectroscopy studies in younger MDD populations, where VLPFC hypoactivation during verbal fluency tasks was associated with suicidality [52, 53]. Similarly, frontal opercular hyperactivity in response to angry faces correlated with poorly planned suicide attempts [40], echoing earlier work in middle-aged attempters showing exaggerated right lateral OFC activity and diminished superior frontal gyrus engagement during a similar task [54]. Notably, such affective dysregulation contrasts with the diminished paralimbic responses to reward, suggesting a dual mechanism where late-life suicide attempters may overreact to negative stimuli while under-responding to positive reinforcers.

Another key finding is the reduction in functional connectivity within the frontoparietal network, which could indicate impaired cognitive control and executive function [55, 56]. These disruptions mirror findings from younger populations with MDD, where disrupted connectivity between prefrontal and parietal regions was predictive of suicidal ideation [57] and reduced rsFC in prefrontal regions was further associated with impulsivity in suicidal adolescents with MDD [58]. This suggests a broader role for altered frontoparietal connectivity in suicidal ideation across different age groups.

In terms of methodological trends, the use of machine learning approaches [34, 35] offers a promising direction for developing predictive models of suicidality based on brain activity patterns. However, the clinical utility of such models remains limited by small, heterogeneous samples, and the lack of external validation. The integration of machine learning into existing care pathways also presents considerable challenges, including the 'black box' nature of complex algorithms which can hinder clinical interpretability, and concerns regarding data privacy and ethical oversight.

Limitations

Several limitations exist within this review. Due to the limited literature, this review did not systematically distinguish between individuals with suicidal ideation and those who had attempted suicide, despite emerging evidence that these states may be neurobiologically dissociable [59–61]. Nevertheless, several observations hint at divergent neural substrates between these states. For instance, VLPFC activation was present in the SI group but absent in the SA subgroup in Hsu et al. [37]; the directionality of connectivity differed between SA and SI groups in Shao et al. [35], though the difference was not statistically significant. Nonetheless, these distinctions remain unclear and require further investigation in larger samples with robust suicidality measures.

Methodologically, cross-study comparisons were complicated by the heterogeneity in LLD diagnostic criteria, exposure, suicidality assessments and analysis methods. The use of antidepressants and other medications may have influenced functional activity independently of suicidality [62, 63]. While most studies reported no significant group differences in medication load or correlations between antidepressant load with functional connectivity, Vanyukov et al. [40] noted that suicide attempters had lower antidepressant exposure than non-suicidal LLD patients, potentially confounding group differences in prefrontal reactivity. Furthermore, not all studies controlled for the duration or severity of depression in their analyses, which could influence the interpretation of significant connectivity changes.

Additionally, most samples were small and predominantly female, potentially limiting the generalizability of findings to broader populations. This gender imbalance reflects the gender paradox in suicidal behaviour, where females exhibit higher rates of SA while males show higher rates of suicide completion [64]. The cross-sectional nature of the data also precludes causal inferences about whether neural changes precede or result from suicidal behaviour, or how suicidal ideation progresses to attempts. Furthermore, there is evidence that rsFC varies depending on the age of MDD onset [65], with distinct patterns of network metrics between late-onset and early-onset LLD [66, 67]. Finally, the screening of abstracts and full-text articles was performed by a single reviewer. This increases the risk of bias in the process of the review.

Clinical Implications

Screening for suicide risk, combined with effective depression treatment, can accelerate the reduction of suicidal ideation in individuals with LLD [68]. While MRI is often used in the clinical evaluation of geriatric depression to exclude underlying medical or neurological conditions, there is growing interest in leveraging fMRI markers to enhance risk stratification and guide individualized interventions. For example, repetitive transcranial magnetic stimulation (rTMS) has emerged as a promising, non-invasive treatment for LLD that modulates large-scale brain networks. Studies employing high frequency rTMS showed clinically significant reduction on depression rating scales [69], while deep TMS achieved remission rates up to 60% in older adults, including those with treatment-resistant depression [70].

However, structural brain changes in LLD, such as age-related cortical atrophy and comorbid vascular pathology, may attenuate the efficacy of conventional rTMS by diminishing the induced electric field [71–73]. To address these challenges, recent studies have utilized fMRI-guided targeting and individualized electric field modelling to optimize stimulation parameters, potentially enhancing therapeutic outcomes [74]. TMS guided by individualized fMRI has also demonstrated greater efficacy compared to other imaging-guided targeting methods [75]. These advances underscore the potential of integrating neuroimaging markers not only for risk assessment but also for optimising neuromodulation strategies.

Conclusions

This systematic review provides the first comprehensive synthesis of functional neuroimaging findings related to suicide risk in late-life depression, revealing disrupted connectivity across frontal, striatal, and limbic regions implicated in cognitive control, emotion regulation, and reward processing. These insights advance our understanding of suicidality in older adults and highlight potential targets for risk assessment and neuromodulatory interventions. Future research should aim to identify neuroimaging markers that distinguish suicide attempts from ideation and employ longitudinal designs to clarify the temporal nature of neural changes relative to the onset of depression and suicidality. Finally, interventional trials will be critical to translating these findings into clinical tools for suicide prevention in this vulnerable population.

List of Abbreviations

BSS: Beck Scale for Suicide Ideation
CCN: cognitive control network
CNN: convolutional neural network
CON: cingulo-opercular network
CPM: connectome-based predictive modelling

DCM: dynamic causal modelling
DLPFC: dorsolateral prefrontal cortex
DMN: default mode network
DSM-5/DSM-IV: Diagnostic and Statistical Manual of Mental Disorders, 5th/4th Edition
DTI: diffusion tensor imaging
EEG: electroencephalogram
FC: functional connectivity
fMRI: functional magnetic resonance imaging
FPN: frontoparietal network
HAM-D: Hamilton Depression Rating Scale
HC: healthy control
LLD: late-life depression
lOFC: left orbitofrontal cortex
MDD: major depressive disorder
MEG: magnetoencephalography
MINI: Mini-International Neuropsychiatric Interview
MMSE: Mini-Mental State Examination
N-S: non-suicidal
OFC: orbitofrontal cortex
PET: positron emission tomography
rHab: right habenula
rsFC: resting-state functional connectivity
rTMS: repetitive transcranial magnetic stimulation
SA: suicide attempt
SCID: Structured Clinical Interview for DSM Disorders
SEN: salience and emotion network
SI: suicidal ideation
SIS: Beck Suicide Intent Scale
SPS: Suicide Probability Scale
TMS: transcranial magnetic stimulation
TSII: Triggers of Suicide Ideation Inventory
VLPFC: ventrolateral prefrontal cortex
VMPFC: ventromedial prefrontal cortex

Conflicts of Interest
The author declares that they have no conflict of interests.

Ethics Approval and/or Participant Consent
This review did not use or collect data requiring ethical approval or participant consent.

Authors' Contributions
LL: made substantial contributions to the design of the study, the collection of data, interpretation and analysis of the data, drafted the manuscript, and gave final approval of the version to be published.

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