Invited commentary

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Lithium treatment and risk for dementia in adults with bipolar disorder†
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Summary
Alzheimer’s disease clinical trials are failing at an alarming rate, highlighting the desperate need for novel thinking to combat this escalating health crisis. A recent large-scale population study indicates that lithium treatment reduces dementia development, supporting preclinical mechanistic evidence that this commonly used agent might be clinically valuable in dementia.

Declaration of interest
None.

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Almost 2% of the UK population has a diagnosis of dementia, and this is expected to rise to more than 2 million by 2051 (150% increase in 40 years). Alzheimer’s disease is the major form of dementia (50–70%) presenting with the unique neuropathological diagnostic characteristics of amyloid plaques coupled to neurofibrillary tangles. Around 20 years ago the amyloid cascade hypothesis proposed that the generation of amyloid beta protein was the initial and central lesion leading to neuropathology, neuronal cell loss, vascular damage and ultimately the symptoms of Alzheimer’s disease. There was real hope that agents targeting this cascade would provide the first therapeutics for Alzheimer’s disease based on disease mechanism. Unfortunately, after many years of research and great expense, this hope has been replaced by real concern that such interventions are not leading to clinical benefit. More than half of all trials of agents designed to interfere with the amyloid cascade have either failed or been halted, with very minor clinical benefit reported in studies completed to date, thus the amyloid cascade hypothesis is under intense scrutiny.

Alternative approaches to prevent Alzheimer’s disease have not been pursued with as much vigour. However, therapeutics to prevent tangle formation have recently entered phase three clinical trials, and an acceptance of the importance of neuro-inflammation and risk factors in dementia development have led to an interest in repurposing currently available drugs for fast tracking into dementia care. Again, the initial results of anti-inflammatory and risk factors in dementia development, supporting preclinical mechanistic evidence that lithium reduces generation of Alzheimer’s disease pathology and cognitive decline in animal models of Alzheimer’s disease. There were no significant benefits on the cognitive measures in this study, however, the authors primarily focused on safety and tolerability, which were deemed acceptable at the doses used, and proposed a longer study was required to assess cognitive improvements. Currently concerns remain regarding the effects of selective GSK3 inhibition. However, lithium, a known inhibitor of GSK3, has been used to treat bipolar disorder for over 50 years.

Although the precise mechanisms of action of lithium remain the subject of debate there is evidence that at least some of its actions are mediated by inhibition of GSK3. The IC50 (50% inhibition constant) for direct GSK3 inhibition in vitro (approximately 0.5 mmol/L) lies at the lower end of the therapeutic range of lithium (0.4–1.0 mmol/L), suggesting that the doses used in clinical practice generate pharmacologically relevant GSK3 inhibition. In addition lithium (unlike more specific GSK3 inhibitors) also reduces GSK3 gene transcription and can induce upstream pathways that negatively regulate GSK3 (at least in rodents and human cells). Therefore, inhibition of GSK3 by lithium in vivo could well be greater than that presumed from in vitro assessed IC50 values. Clearly the actual dose–response association between lithium and GSK3 activity in humans requires robust experimental evaluation, but the preclinical evidence suggests that lithium reduces activity of an enzyme proposed as a therapeutic target in Alzheimer’s disease. This raises two important questions: (a) does lithium treatment have any therapeutic efficacy in Alzheimer’s disease, and (b) if therapeutic efficacy is related to GSK3 inhibition would more selective GSK3 inhibitors be worth pursuing as novel Alzheimer’s disease therapeutics?

Lithium and dementia
Lithium administration to rodent models of Alzheimer’s disease reduces generation of Alzheimer’s disease pathology and cognitive decline. Of course, there is serious concern over the translation of...
findings in rodents to humans. However, lithium increases both grey matter and N-acetyl-aspartate levels in human brain, supportive of a neuroprotective action of lithium in humans. The importance of GSK3 inhibition in these actions of lithium requires validation, as there are other targets of lithium proposed to be neuroprotective. Lithium regulates calcium levels through inositol monophosphatase and/or N-methyl-D-aspartate (NMDA) receptors, and regulates autophagy, apoptosis and mitochondrial function. Lithium increases serum brain-derived neurotrophic factor (BDNF) levels in Alzheimer’s patients and induces the repressor element 1-silencing transcription factor (REST), a protein known to decline in Alzheimer’s disease (and in mild cognitive impairment). REST induces genes that antagonise cell death and is thus neuroprotective (Fig. 1). Taken together this indicates that lithium has multiple potential mechanisms that would antagonise processes associated with dementia.

The belief that lithium has severe toxicity in humans has limited its investigation in trials for dementia protection almost exclusively to people with bipolar disorder. Two initial observational studies generated opposite conclusions, one study suggesting that lithium promoted dementia development in patients with bipolar disorder, the second finding protection with lithium. Subsequently two Danish studies indicated a major reduction in dementia associated with long-term lithium use. More recently a pilot study of lithium treatment in mild cognitive impairment indicated a trend towards cognitive benefit (and 91% tolerability) but this trial was too short to investigate conversion to dementia. Similarly, 10-week treatment in mild cognitive impairment indicated a trend towards cognitive benefit (and 91% tolerability) but this trial was too short to investigate conversion to dementia. These studies support the notion that lithium can be tolerated in patients with mild cognitive impairment or Alzheimer’s disease, and it can improve pathological markers, but like most interventions for dementia more chronic treatment will be required to assess effects on symptoms, and these may only be apparent in earlier stages of the disease.

In support of this, a small randomised, controlled trial found that relatively low-dose (300 μg daily) lithium for 15 months reduced cognitive decline in Alzheimer’s disease patients, and now, the largest retrospective epidemiological analysis of dementia diagnosis in older adults treated with lithium ever conducted (n > 40,000) has provided the most convincing evidence to date that lithium protects against progression to dementia. Continuous lithium treatment for 10–12 months...
reduced the development of clinical dementia (all forms) when compared with two groups of patients with bipolar disorder receiving shorter, intermittent lithium or no lithium (anti-convulsants). Although such studies are fraught with confounding issues, the association between continuous lithium use and lower risk of dementia held true through adjustment for over 20 covariates. This robust and extensive study provides real optimism that there is a cheap, ready-to-use drug available that could prevent or slow down the development of dementia.

An opportunity too good to pass up?

Should lithium be fast-tracked to clinical trials? The lack of progress in developing therapeutics for dementia would suggest yes, although many key questions remain. Will lithium have efficacy in all groups at high risk of developing dementia (for example mild cognitive impairment, diabetes)? Does the observational data support a causal relationship between lithium and the reduced development of dementia? The data available would suggest that clinical trials should focus on the prodromal phase of Alzheimer’s disease, mild cognitive impairment, since this phase is more likely to be amenable to manipulation of the proposed lithium targets than established disease.

In summary, new clinical data suggest lithium has the potential to prevent dementia development. With little evidence of novel therapeutics on the horizon for the millions of people at risk of dementia it would seem negligent not to investigate lithium in dementia prevention more thoroughly.

References

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