HDL: Close to Our Memories?

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The last decade has witnessed an explosion in studies of the role of lipoproteins in brain function. Neurons require a continuous supply of lipids for membrane synthesis and acetylcholine production. Indeed, the brain is a site of intense lipid turnover—even though the central nervous system (CNS) accounts for only 2.1% of body weight, it contains 23% of total body cholesterol.1 Lipid metabolism in the brain is tightly controlled locally, as plasma lipoproteins are shielded from the brain by the blood-brain barrier. Although neuronal cells are capable of de novo synthesis of a wide spectrum of molecular species of lipids, they rely heavily on exogenous sources and readily bind and internalize lipoproteins of the extracellular fluid.2 Equally, neurons need to dispose of excess lipids; lipoprotein-mediated lipid transport is therefore bidirectional and includes cellular efflux of cholesterol.3

The metabolism of CSF lipoproteins remains poorly characterized but seems to be distinct from that of plasma lipoproteins. ApoE-rich HDL are synthesized locally in CNS and secreted by astrocytes as discoidal complexes enriched in free cholesterol.6 High apoE content targets these lipoproteins to cellular apoE receptors, particularly LDL receptor–related protein, which is abundantly expressed on the surface of neurons.2 By contrast, apoA-I–rich CSF lipoproteins are most probably derived from plasma HDL that enter the CNS by crossing the blood-brain barrier,7 as apoA-I is not synthesized in the CNS.2 Similar to plasma HDL, CSF lipoproteins can be remodeled by lecithin-cholesterol acyltransferase and phospholipid transfer protein; by contrast, cholesteryl ester transfer protein (CETP) is absent from CSF.3 These data clearly demonstrate that brain HDL constitute a key element of cholesterol homeostasis in the CNS.

Over the past decade, abnormalities in brain lipid metabolism are increasingly recognized to be intimately related to the pathogenesis of such major neurodegenerative disorders as Alzheimer disease (AD) and vascular dementia (VD). With respective frequencies of 70% and 15% of all dementias, AD and VD are the most common forms of dementia which are typically preceded by less dramatic cognitive decline, including decline in memory.8 Both AD and atherosclerosis develop in parallel with the aging process and as such, share a number of risk factors, including the presence of Type 2 diabetes and elevated levels of total cholesterol and Lp(a) in midlife, thereby suggesting common pathophysiological pathways.9 Indeed, progression of both AD and atherosclerosis in animal models critically depends on the expression of specific apolipoproteins, such as apoE; furthermore, both diseases involve chronic local inflammation, either in the brain or in the arterial wall, as a key pathological feature.

Low levels of HDL-cholesterol (HDL-C) are firmly established as a major risk factor for cardiovascular disease (CVD), and HDL is presently the focus of attention as a promising therapeutic target to reduce CVD.10 The question that intrigues every lipidologist is, therefore: does the protective function of HDL hold true in AD, VD, and other dementias? The study of Singh-Manoux et al11 in the current issue of the Journal suggests an association between low plasma levels of HDL-C and short-term verbal memory deficits in middle-aged adults. Furthermore, fall in HDL-C over a 5-year follow-up was associated with decline in memory. These associations remained after adjustment for educational level, occupational position, prevalent disease, and medication use. Interestingly, the associations between low HDL-C levels and memory deficits were independent of the presence of the apoE4 allele, a potent risk factor for AD. By contrast, circulating concentrations of total cholesterol and triglycerides did not display significant association with memory deficit or decline. Do these undoubtedly interesting results firmly place HDL-C in our memories?

Although earlier observational studies on the relationship between HDL-C levels and cognitive function produced conflicting results (see12,13 for review), low plasma concentrations of HDL-C have been repeatedly reported in association with dementia. As the majority of earlier studies were cross-sectional, the present study is clearly distinct as a result of the evaluation of both cross-sectional and prospective associations. Moreover, elevated HDL-C levels potentially mediated by low CETP activity are also associated with longevity, improved cognition, and dementia-free survival.14 Inversely, CETP polymorphisms resulting in low HDL-C are

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prevalent in AD. However, none of these studies infers causality because, as Singh-Manoux et al rightly point out, plasma lipid levels can be considerably modified over the development of dementia, making the time point of the measurement critically important.

The key question that was not addressed by the authors is, therefore: which mechanisms underlie these effects? Singh-Manoux et al mention vastly different neuroprotective properties of HDL which include accelerated maturation of synapses, maintenance of synaptic plasticity, improved metabolism of Aβ, and increase in hippocampal volume, later adding antiinflammatory and antioxidative activities to the list—just to illustrate how complex and variable biochemical mechanisms potentially linking HDL to AD might be.

The complexity of the mechanistic relationship between HDL and brain function is immediately apparent when we look at Aβ metabolism, the major pathway involved in the pathogenesis of AD. Brain HDL can exert several neuroprotective effects acting only via this pathway (Figure). First, as neuronal production of Aβ frequently parallels membrane content of cholesterol, HDL can suppress Aβ production by decreasing cellular cholesterol through the activation of reverse cholesterol transport mediated by ABC transporters. Second, HDL can directly bind excess Aβ and thereby inhibit its oligomerisation, the latter representing a major step in the transformation of the monomeric nontoxic peptide to the aggregated neurotoxic form that can account for memory impairment. As HDL transports Aβ in both CSF and plasma, elimination of the excess peptide from the brain may follow. In addition, HDL might also remove Aβ that accumulates in the vessel wall during the course of VD; by analogy with reverse cholesterol transport, such a process can be termed “reverse amyloid transport.” Third, oxidative stress induces enhanced production of Aβ as a potentially protective response (monomeric Aβ is a particularly strong chelator of prooxidant transition metal ions in their free form); in turn, HDL can decrease oxidative stress and thereby indirectly decrease Aβ production. Fourth, HDL can act on astrocytes to attenuate a local inflammatory reaction.

In all of these scenarios, it remains unclear as to how low levels of HDL-C measured in plasma can be translated into defective functionality of HDL in the brain. ApoA-I, the major component of plasma HDL implicated in cellular cholesterol efflux and other biological activities of HDL, might represent a potential link. Plasma levels of HDL-C and apoA-I are strongly correlated in the general population; it is therefore possible that levels of apoA-I decrease in parallel with those of HDL-C in subjects with memory deficit. Cholesterol removal from neuronal cells together with reduced neuroinflammation, both mediated by apoA-I that has crossed the blood-brain barrier, might then mechanistically underlie the relationship between low HDL-C levels and memory deficits observed.

Finally, classical inhibition of large-vessel atherosclerosis by HDL is another interesting possibility, as vascular pathology may play a common role in initiating neurological deficits in AD and VD.

The authors rightly list a number of limitations of their study, including its observational nature, potentially incomplete adjustments for confounders (such as smoking habits, alcohol use and physical exercise), all of which can strongly impact on HDL-C levels), above-average socioeconomic status of the participants, and potential survival and selection bias attributable to follow-up. This list should be further extended to include the absence of the distinction between fasting and nonfasting subjects as well as between men and women. Indeed, HDL-C levels strongly depend on sex and can be altered in the postprandial state. The low proportion of women in the study population (<30%) questions the applicability of the results to females. In addition, a more traditional presentation of plasma lipid levels as continuous, instead of categorical, variables could have provided more detailed information on their relationships to memory deficits. Next, decreasing cardiovascular risk concomitant with increasing HDL-C levels and decreasing total cholesterol with age observed in this study is not a straightforward finding, but most probably related to the 3.7-fold elevated use of lipid-lowering drugs; such a limitation should have additionally decreased the number of subjects displaying decreasing concentrations of HDL-C on follow-up, thereby reducing statistical power.

Finally, the absence of data on the incidence of diabetes and obesity in the Whitehall population is regrettable. Type 2 diabetes shares metabolic features with AD, as the number of pathways shared by these 2 major pathologies is evolving progressively; for example, elevated levels of insulin result in elevated generation of Aβ peptide. As subnormal levels of HDL-C are a hallmark of Type 2 diabetes, the increasing prevalence of this disease in low HDL-C subjects might well underlie the association with memory decline observed by Singh-Manoux et al. Whatever the case, the link between AD and HDL-C remains to be elucidated.
Type 2 diabetes, low HDL-C, and memory decline is worthy of further study.

It is tempting to speculate that increasing levels of HDL-C, or “good cholesterol”, might protect our good memories and the authors do not escape this temptation. However, unfortunate results in large interventional trials with dietary antioxidants suggest that we should remain extremely cautious when proposing therapeutic intervention on the basis of observational studies which do not imply causation. This is particularly true for a study with a number of important limitations such as that of Singh-Manoux et al. For example, a close look at their data shows that whereas falling HDL-C over the time of the study was associated with deterioration of memory, increase in HDL-C concentrations was not associated with improved memory as compared to their stabilization (Table 4). As a minimum, such observational data should be strengthened using direct neuroanatomical and neurofunctional approaches instead of simple memory tests. Thus, HDL-C remains a potentially promising but unproven marker.

In summary, the authors do not escape this temptation. However, unfortunately, results in large interventional trials with dietary antioxidants suggest that we should remain extremely cautious when proposing therapeutic intervention on the basis of observational studies which do not imply causation. This is particularly true for a study with a number of important limitations such as that of Singh-Manoux et al. For example, a close look at their data shows that whereas falling HDL-C over the time of the study was associated with deterioration of memory, increase in HDL-C concentrations was not associated with improved memory as compared to their stabilization (Table 4). As a minimum, such observational data should be strengthened using direct neuroanatomical and neurofunctional approaches instead of simple memory tests. Thus, HDL-C remains a potentially promising but unproven marker.

Disclosures

None.

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