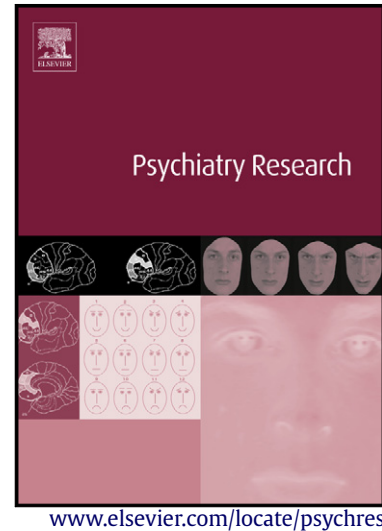# Author's Accepted Manuscript

Lovastatin for the adjunctive treatment of schizophrenia: A preliminary randomized double-blind placebo-controlled trial

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Lovastatin for the adjunctive treatment of schizophrenia: a preliminary randomized

double-blind placebo-controlled trial

Short title: Lovastatin and schizophrenia

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ABSTRACT

  While statins target many of the pathways to neuroprogression in schizophrenia, the safety and efficacy of statins for treating schizophrenia has never been examined.

This is an 8-week randomized double blind controlled clinical trial examining the efficacy and safety of adjunctive lovastatin (20 mg /day) treatment or placebo for people with schizophrenia.

The baseline characteristics of the two groups were not different. Endpoint changes in Positive and Negative Syndrome Scale (PANSS) total and subscale scores did not differ between the two groups. However there was a significant difference between the doses of risperidone used in the two groups. The mean dose in the lovastatin and placebo groups were 4.8(1.8) and 3.4(1.4) mg/day, respectively (P<0.03). No serious adverse events were reported. Slowness of movements, muscle rigidity, increased appetite, and decreased energy were the most common adverse effects, and these rates did not differ between the two groups.

This study failed to demonstrate a benefit of lovastatin on symptoms of schizophrenia. This combination was well tolerated. However, a higher dosage of risperidone was used for treating the disorder in those taking concomitant lovastatin compared to placebo.

This trial was registered at http://www.irct.ir. The registration number of this trial was Irct registration number: IRCT201304143930N21

http://www.irct.ir/searchresult.php?keyword=lovastatin&id=3930&number=21&field=g&prt=4 &total=5&m=1

1. Introduction

Schizophrenia is a disorder of unknown etiology. Inflammation is one possible etiological pathway with studies investigating the role of a number of cytokines including interleukin 1(IL-1) and interleukin 6 (IL-6) in patients with schizophrenia (Berk et al., 2008b; Song et al., 2009). In people with schizophrenia, serum levels of interleukin-1beta (IL-1beta) (Chang et al.; Soderlund et al., 2009; Song et al., 2009) and tumor necrosis factor-alpha (TNF-alpha) are higher than that of those healthy subjects (Song et al., 2009). IL-1 activates and increases nuclear factor kappa-light-chain-enhancer of activated B cells (NF-kappaB), whose activity is also increased in schizophrenia(Song et al., 2009). However, the data regarding increased levels of IL-6 are inconsistent (Singh et al., 2009). A meta-analysis of cytokines in schizophrenia suggests that interleukin-1β, interleukin-6, and transforming growth factor-β may markers of acute illness exacerbations, while interleukin-12, interferon-γ, tumor necrosis factor-α, and soluble IL-2 receptor may be trait markers of the disorder (Miller et al., 2011). Antipsychotics have effects on cytokines, with a recent meta-analysis showing reduction in pro-inflammatory cytokines such as interleukin-1β and interferon-γ, and reduction in plasma levels of soluble interleukin-2 receptor (Tourjman et al., 2013). Germane to this study, risperidone decreases serum levels and mRNA expression of IL-1beta in people with schizophrenia (Song et al., 2009).

There is an increased risk of schizophrenia in children of the mothers who experience infection in pregnancy. A single maternal injection of IL-6 to a pregnant mouse causes expression of a model of schizophrenia in adult offspring, while IL-6 knock-out mice do not show these features

(Smith et al., 2007). Pro-inflammatory cytokines such as IL-1beta induce lethargy, anhedonia, social withdrawal, and cognitive problems that are analogous to the negative symptoms and cognitive problems in schizophrenia and depression (Dantzer and Kelley, 2007). IL-1beta also causes dopaminergic and glutamatergic abnormalities akin to those reported in schizophrenia (Soderlund et al., 2009). Anti-inflammatory effects of IL-6 is mediated through inhibition of TNF-a and IL-1, and activation of IL-1ra and IL-10 (Donev and Thome).

These findings led researchers in schizophrenia to conduct studies to examine if reducing inflammation might be of clinical benefit. Add-on treatment with celecoxib plus risperidone was superior to risperidone alone in decreasing positive symptoms of schizophrenia (Akhondzadeh et al., 2007; Muller et al., 2002). Celecoxib inhibits activity of cyclooxygenase-2 (COX-2), a mediator of inflammation in the brain. Cytokines such as Il-6, IL-10, and Il-2 activate this enzyme. As levels of IL-6 (Akiyama, 1999; Kim et al., 2009) and IL-10 are high in schizophrenia, celecoxib down-regulates COX-2 activity leading to the reduction of inflammation. In a similar manner, aspirin which is the original anti-inflammatory agent (Berk et al., 2013), improved the core features of schizophrenia (Laan et al.). A recent meta-analysis of anti-inflammatory treatment of schizophrenia documented the potential utility of COX-2 inhibitors and minocycline in schizophrenia (Fond et al., 2014).

Statins are widely used and effective lipid lowering agents. They inhibit 3-hydroxy- 3-methylglutaryl-CoA reductase. However, statins have other effects which are cholesterol independent such as decreasing oxidative stress and inflammation. Recently, it has been shown that statins inhibit brain inflammation. Simvastatin inhibits inflammation by the reduction of IL-

1beta and TNF- alpha (Hernandez-Romero et al., 2008). It also increases BDNF expression which has neuroprotective effects (Hernandez-Romero et al., 2008). Atorvastatin decreases IL-βand TNF- αexpression as well as the production of IL-1β, IL-6 and TNF-α in the hippocampus (Zhang et al., 2013). Atorvastatin is thus a potential neuroprotective agent (Castro et al., 2013). Lovastatin significantly decreases mRNA expression of IL-1beta, IL-6, TNF- alpha, and kinin B1 receptor in animals (Chen et al., 2007; Gouveia et al.). There is data that they may have psychotropic effects especially in depression (Ghanizadeh and Hedayati, 2013; O'Neil et al., 2012). A recent meta-analysis reported that statin use may be associated with a lower risk for the development of depression (Parsaik et al., 2013). However, a retrospective, observational, population-based study did not show any association between statin use and the risk of development psychological disorders (Mansi et al., 2013).

Moreover, dyslipidaemia in people with schizophrenia is very common. Some psychotropic agents, particularly atypical antipsychotics, increase lipid levels (Wirshing et al., 2002). Furthermore, a sedentary lifestyle is common in schizophrenia, increasing the risk of cardiovascular problems. Lipid lowering medications reduce cardiovascular risk by decreasing triglycerides and cholesterol (Expert Panel on Detection and Treatment of High Blood Cholesterol in, 2001). Rosuvastatin decreased dyslipidemia in patients with schizophrenia treated with antipsychotics (De Hert et al., 2006). A study reported absence of pharmacological interactions between clozapine and lovastatin and atorvastatin and pravastatin (Landry et al., 2008). A retrospective study showed that statins decreased total cholesterol, triglycerides, low-density lipoprotein cholesterol (LDL-C), and high-density lipoprotein cholesterol (HDL-C) (Vincenzi et al., 2013). Statins may consequently be considered as a potential primary preventive

and treatment approach in schizophrenia. Nevertheless, the efficacy and safety of statin use in psychotic disorders in terms of psychiatric endpoints has not been investigated (Mascitelli et al., 2008).

Concordant with the above mentioned evidence, it was not a primary hypothesis that lovastatin, on the basis of its anti-inflammatory effects, may decrease symptoms of schizophrenia using the PANSS but as a post-hoc finding.

2. Methods

2.1. *Participants*

This is a randomized double-blind placebo-controlled add-on trial in patients with schizophrenia. The clinical sample consisted of 36 inpatients with schizophrenia in the active phase of this disorder diagnosed according to DSM-IV diagnostic criteria. They were randomized in a 1:1 ratio to lovastatin (20mg/day) or placebo. The starting dose of lovastatin was 10 mg/day titrated up 20 mg/day after one week. The duration of study was 60 days. All participants both groups were concurrently administered risperidone (2 to 8 mg/day).

Inclusion criteria were: a diagnosis of schizophrenia using DSM-V diagnostic criteria, written informed consent provided by the patient and/or caregiver, aged between 18 and 66 years of age, not currently taking a statin medication, no evidence of active substance abuse or dependence and a PANSS baseline total score of ≥50. Use of concomitant non-investigational medications such as biperidin was permitted.

Exclusion criteria were: use of long acting antipsychotics in the last 2 months prior to this study, serious medical or neurological illness such as seizures, hypothyroidism, diabetes, encephalitis, liver disease, cancer, unstable heart failure, uncontrolled hypertension/asthma/COPD; psychotic disorder due to a general medical condition or substance use, use of medications with significant interactions with lovastatin, pregnant women or the patients planning to be pregnant during this study, or women not using adequate birth control methods , lactation, currently taking a statin or any of the following: anti-inflammatory drugs or aspirin; systemic antibiotics, anti-viral or anti-fungal drugs (within the past 4 weeks); potent inhibitors of the cytochrome P450 isoform 3A4 (CYP3A4) including digoxin, nefazodone, cyclosporine, warfarin, amiodarone or verapamil.

The mean dose of risperidone required for treating patients with schizophrenia was at clinician discretion. The Positive and Negative Symptoms Scale (PANSS) (Kay et al., 1987) was used to evaluate the clinical symptoms of schizophrenia. Treatment emergent adverse effects were evaluated using a checklist.

Considering a difference of 4 points on the PANSS total score between the lovastatin and placebo groups, a standard deviation (SD) of 4, a two-tailed P<0.05, and a power of 80 %, a sample size of 34 was calculated.

2.2 *Statistical analysis*

Data analysis was performed using SPSS for windows. Intention-to-treat analysis (ITT), using last observation carry-forward (LOCF) method, was used to impute missing data related to any participants who dropped out this trial. Mann–Whitney tests were performed to compare age,

body mass index, PANSS total score, PANSS negative total score, PANSS positive total score, and PANSS general psychopathology total score between the two groups. Chi-squared tests were used to compare the gender ratio, marital status, and subtype of schizophrenia between the two groups. Fisher's exact test was used to compare categorical variables between the two groups whenever applicable. P values less than 0.05 were considered significant.

3. Results

Three screened patients did not provide informed consent, and were not entered this trial. There were 20 patients in the lovastatin group and 16 patients in the placebo group. Six participants (4 in the lovastatin group and 2 in the placebo group) dropped out after the third assessment. Medication adherence of six participants was poor, and they were excluded. No participants dropped out due to treatment emergent adverse effects. A consort flow chart is shown in figure 1.

The mean age (SD) of the patients in the lovastatin and placebo groups was 30.8(8.9) and 30.1(6.5) years, respectively (P=0.7). The mean years of education, smoking rates, marital status, schizophrenia subtype, baseline total PANSS score, baseline PANSS positive score, baseline PANSS negative score, baseline PANSS general psychopathology score and body mass index (BMI) did not differ between the groups (Table 1).

Table 2 shows the change in PANSS score from baseline to week 8 by treatment allocation. PANSS total and subscale scores were not different between the two groups. In addition, the PANSS total score significantly decreased in both groups over time, but there was no statistically significant difference between the two groups (P=0.3) (it is available as a Supplementary file).

However, there was a significance difference between the final dose of risperidone between the two groups (P<0.03). The mean dose in the lovastatin and placebo group was 4.8(1.8) and 3.4(1.4) mg/day, respectively.

The combination of risperidone and lovastatin was well tolerated and there were no serious adverse effects. Slowness of movements, muscle rigidity, increased appetite, and decreased energy were the most common adverse effects, but these did not differ between the groups, and are known adverse effects of risperidone. Decreased energy and decreased libido were non-significantly more common in the lovastatin group than the placebo group (the Table of side effects is available in electronic supplementary file).

4. Discussion

This is the first randomized double blind placebo controlled clinical trial examining the efficacy and safety of a statin for treating patients with schizophrenia. The hypothesis of the study, that statin treatment would be associated with symptomatic improvement was not supported by this study. This finding is in contrary to our hypothesis. We expected that lovastatin would augment the efficacy of risperidone in treating schizophrenia. However a finding of this trial was that that a higher dosage of risperidone was used for treating participants taking lovastatin as an adjuvant medication.

There are several possible explanations for this finding. First of all, there are some contradictory reports about the role of interleukins in schizophrenia. For example, a study failed to show the

increased level of IL-6 in schizophrenia (Singh et al., 2009). Secondly, it is not clear if lovastatin affect all these cytokines as this class of cytokines have diverse neurodevelopmental and neuroregulatory roles (McAllister et al., 1995). Therefore, it is unclear how lovastatin impacts the balance between the proinflamatory and anti-inflammatory interleukins. Third, all of the participants were inpatients, who are usually the most severely ill individuals. Fourth, it is possible that there are pharmacological interactions between lovastatin and risperidone. However, no significant adverse effect or pharmacological interactions between clozapine and lovastatin, atorvastatin or pravastatin were reported (Landry et al., 2008). Fifth, the duration of this study was probably not long enough to detect any beneficial effect of lovastatin on schizophrenia symptoms. As an exemplar, N-acetylcysteine, which is also thought to act on oxidative an inflammatory pathways, only showed clear evidence of efficacy after 6 months (Berk et al., 2008a; Berk et al., 2008b) . Sixth, risperidone decreases serum level of IL-1beta in schizophrenia (Song et al., 2009). It is possible that lovastatin adds nothing further to this effect. Seventh, statins differ in their lipophilicity, with only lipophilic agents crossing the blood brain barrier; while lovastatin is lipophilic, its bioavailability is relatively poor (Chen et al., 2010). Lastly, the study was only small and thus only powered to detect large effects, and would be incapable of detecting small or medium effects. As adverse events only occur in a subset of trial participants, the study is also underpowered to detect patterns of adverse events. Given the success of pilot studies of statins in depression (Ghanizadeh and Hedayati, 2013), further trials with a larger sample size and longer duration are needed.

Abnormalities in fatty acid composition and metabolism have been reported in patients with schizophrenia (Hoen et al., 2013). For example, the levels of docosapentaenoic acid (DPA), docosahexaenoic acid (DHA), and arachidonic acid (AA) are decreased (Hoen et al., 2013).

Moreover, changes in the levels of n-3 polyunsaturated fatty acids (PUFAs), especially DHA, are probably specific to some regions (Hamazaki et al., 2013). Future studies may investigate the possible association of abnormal fatty acid levels and negative effects of lovastatin in the patients with schizophrenia.

In conclusion, this study did not support the potential efficacy of statin augmentation of risperidone in schizophrenia, however taking concurrent lovastatin with risperidone may increase the required dosage of risperidone compared to risperidone alone for treating the clinical symptoms of schizophrenia. One has always to be more cautious in interpreting secondary than primary findings. The combination of lovastatin and risperidone was however well tolerated. Larger trials capable of detecting small or medium effect sizes are warranted.

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Statement of interest:

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Table 1 The baseline characteristics of the patients in both groups

	lovastatin + risperidone	Placebo + risperidone	Significance
Number (%) of men	13 (68.4%)	11 (68.8 %)	X2=.05, df=1, P=.8
mean (SD) years of age	30.8(8.9)	30.1 (6.5)	t=.2, df=34, P=.8
Body Mass Index	20.7(5.0)	23.3(5.7)	P=.1
Marital status, n (%)			
Single	14 (70.0 %)	12 (75.5 %)	X2=.18, df=2, P=.9
Married	4 (20 %)	3 (18.8 %)	
Divorced	2 (10.0 %)	1 (6.2 %)	
Mean (SD) years of education	9.8(3.4)	9.4(5.2)	t=.2, df=33, P=.7
Smoking, n (%)	3 (15 %)	4 (25 %)	X2=.5, df=1, P=.4
Mean (SD) years duration of illness	.5 (1.2)	0.9 (2.4)	t=.5, df=31, P=.5
Number (%) of schizophrenia type			
•Paranoid	7 (58.3 %)	4 (40.0 %)	P=.6
•Residual	3 (25 %)	4 (40 %)	
•Undifferentiated	5 (20 %)	4 (16 %)	
Prior antipsychotic medications, n (%)			
•Risperidone	10 (50 %)	9 (56.2 %)	
•Olanzapine	4 (20 %)	2 (12.5 %)	
Baseline scores, mean (SD)			
•PANSS total score	129.9 (15.8)	123.8 (18.1)	P=.2
•PANSS negative subscale	26.9 (5.76)	25.4 (4.61)	P=.2

|	lovastatin + risperidone	Placebo + risperidone	Significance
•PANSS positive subscale	30.8 (6.6)	31.1 (6.0)	P=.8
•PANSS general psychopathology subscale	70.6 (9.3)	68.3 (12.5)	P=.4
List of concurrent medications n(%)			
Clonazepam	4(20)	3(18.8)	P=1.0
Biperidin	12(60)	11(68.8)	P=.4
Trihexyphenidyl	6(30)	1(6.2)	P=.08
Alprazolam	2(10)	0	P=.3
Lorazepam	1(5)	4(24.8)	P=0.02
Lithium	1(5)	0	-
Sodium valproate	1(5)	0	-
Citalopram	1(5)	0	-

PANSS positive and negative syndrome scale

Table 2 Change in PANSS score from baseline to week 8 by the treatment groups

	PANSS total score	PANSS negative score	PANSS positive score	PANSS global score
lovastatin group	-43.0(13.8)	-4.9(8.1)	-11.7(4.3)	-24.4(8.3)
Placebo group	-40.6(13.8)	-5.9(3.4)	-11.6(4.0)	-24.3(6.3)
Significance	0.9	0.8	0.7	0.8

Highlights

➢ Lovastatin no more than placebo was effective.
➢ No serious adverse effect was reported.
➢ Lovastatin may increase the required dosage of risperidone.

Figure 1 Flowchart for the clinical trial of lovastatin group versus placebo group.
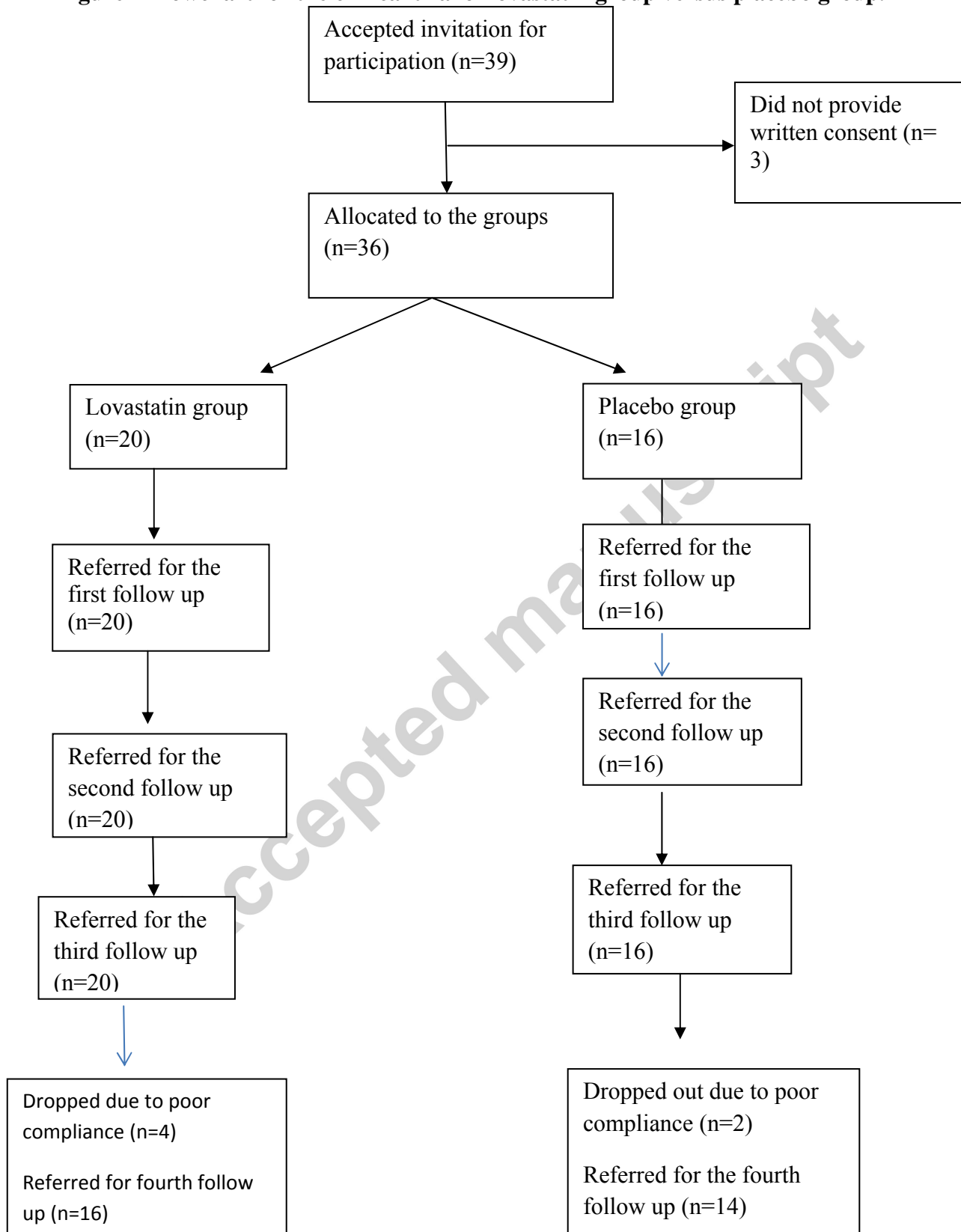
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