Lipid-Lowering Agents

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 Agents used in HT, CHF, Arrhythmia and Angina

<table>
<thead>
<tr>
<th>Drug Class</th>
<th>Hyper-tension</th>
<th>HF</th>
<th>Arrhythmia</th>
<th>Angina</th>
<th>Contradictions/Cautions/Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beta-Blockers</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>HF (Cl: unstable HF, broncho-spasm, significant bradycardia, depression): Raynold D. Caution in diabetes, asthma (see ↓)</td>
</tr>
<tr>
<td>Ca++-Channel blockers</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>HF, constipation, gingival hyperplasia, edema, reflex tachycardia</td>
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<tr>
<td>ACEI / ARBs</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>Angioedema; hypertokalemia, cough (ace), tetrogenic, glossitis, taste</td>
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<tr>
<td>Diuretics (Thiazides)</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>GFR &gt;30, hypotokalemia (Cl), Tca++, diabetes (↑ glucose tolerance)</td>
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<tr>
<td>Cardiac glycosides</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>Many Rx interactions, (K+L), Lase HF important, low K+ = toxicity</td>
</tr>
<tr>
<td>Vasodilators</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>Flushing, diziness, headache, nausea, reflex tachycardia</td>
</tr>
<tr>
<td>Nix-Channel blockers</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>Effects enhanced in depolarated, damaged tissue, Phase 0, ↓ CV</td>
</tr>
<tr>
<td>Nitrates</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>NOx/GMP, tolerance (off periods), flushing, diziness, headache, reflex tachycardia, many forms</td>
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</table>

Leading Causes of Death in the U.S

Top Causes of Death (%), U.S.

Data NIH 2000

Relative Risk for CHD vs Total Cholesterol

Abbreviations and Definitions (Lipids)

- TG [Triglyceride] VLDL, IDL, CM
- FFA [Free Fatty Acids] TG, primary energy source
- C [Cholesterol] VLDL, IDL, LDL, HDL, CM
- CE [Cholesterol ester] VLDL, IDL, LDL, HDL, CM
**Abbreviations and Definitions (Lipoproteins)**

- **VLDL** [very-low-density lipoprotein] [TG / CE] Apo B-100 [ATH]
- **IDL** [intermediate-density lipoprotein] [TG / CE] Apo B-100 [ATH]
- **LDL** [low-density lipoprotein] [TG / CE] Apo B-100 [very ATH]
- **HDL** [high-density lipoprotein] [C / CE] Apo A, C, E [non-ATH]
- **CM** [chylomicrons] [TG / CE] Apo B-48 [non-ATH]

**Relative size, density and TG/Chol ratio of different lipoproteins**

- Chylomicron: 95% TG, 5% Chol
- HDL: 5% TG, 95% Chol
- LDL: 10% TG, 90% Chol
- IDL: 50% TG, 50% Chol
- VLDL: 80% TG, 20% Chol

**Abbreviations and Definitions (Apoproteins)**

- **CII** apoprotein CII [lipoprotein lipase activator] [HDL]
- **A-1** apoprotein A-1 [LCAT cofactor] [HDL]
- **E** apoprotein E [required for LP binding to receptors] [HDL]
- **B-48** apoprotein B-48 [structural apo for CMs]
- **B-100** apoprotein B-100 [structural apo for VLDL, IDL, LDL]

**Abbreviations and Definitions (Enzymes)**

- **LPL** Lipoprotein [TG] Lipase TG ⇒ FFA [VLDL, CM]
- **HMG-CoA Reductase** – Rate limiting step C synthesis
- **CETP** Cholesterol ester transfer protein (HDL) CE [HDL] exchanged for TG in lipoproteins
- **LCAT** Lecithin:Cholesterol Acyltransferase (HDL) takes up lipoprotein C and ⇒ CE for CETP

**Atherosclerosis**

**Significance:** Major cause of death in U. S.

**Pathogenesis:**

Injury/inflammation to blood vessel and infiltration of LDL and platelets. Formation of foam cells when LDL (oxidized) is internalized. Blood vessel is narrowed by plaque and blood clot reduces blood flow to brain (stroke) and heart (heart attack).

**Pathogenesis of Atherosclerosis**

1. **Cell Injury**
2. **Cell Proliferation**
3. **Plaque Formation**
Atherosclerosis: An Inflammatory Disease

Atherosclerosis Timeline

Adapted from Pepine CJ. Am J Cardiol. 1998;82(supp1):104.

Coronary Occlusion

Surgical Treatment
(Coronary bypass, angioplasty, stents)

Atherosclerosis

Risk Factors:
- Hypertension
- Diabetes
- Stress
- Family history

- age
- high fat diet
- low HDL
- High levels of VLDL, IDL, and LDL.

- obesity
- smoking
- lack of exercise

Treatment: appropriate diet and drugs lowers mortality and morbidity 20 to 40%.

LDL Structure

10% TG; 90% C

APOPROTEIN B100

CHOLESTEROL

PHOSPHOLIPID

CHOLESTEROL ESTER

TG, apo CII, E

AI & B48
Lipoprotein Metabolism I

Factors Increasing HDL Levels

1. Exercise
2. Moderate Alcohol Intake
3. Weight Reduction (overweight)
4. Stop Smoking
5. Lipid-lowering drugs (Resins, Statins, Fibrates, Ezitimibe & Niacin)

Increased HDL levels are antiatherogenic
HDL enhances the clearance of LPs and Cholesterol

Not a Moderate Drink

Primary Hyperlipidemia (fasting blood sample)

Hypertriglyceridermia (TG 400-2,000 mg%) [PA= pro-atherosclerosis]
1. Increased CMs (low LPL), non-atherogenic
2. Increased CMs and VLDLs (low LPL & increased VLDL production) [PA]
3. Increased VLDDL (increased VLDL production and decreased LPL) [PA]
4. Increased IDL & CM remnants (decreased clearance, low apo E) [PA]

Hypercholesterolemia (C 250-800 mg%)
1. Increased VLDDL and LDL (increased VLDL production) [PA]
2. Increased LDL (increased LDL production and decreased LDL clearance) [PA]
3. LDL receptors in genetic disorders, 50% heterozygote and 100% homozygote [PA].
Secondary Hyperlipidemia

Hypertriglyceridemia (VLDL)
Diabetes, oral contraceptives (estrogen), hypothyroidism, hypopituitarism, high sugar diet and high alcohol intake (increased production and decreased clearance of VLDL).

Hypercholesterolemia (LDL)
High cholesterol (fat) diet, hypopituitarism and hypothyroidism (decreased LDL receptors).

Resins - MOA

Resins: Colestipol, Cholestyramine and Colesevelam
1. Bind bile salts and block enterohepatic cycle of bile acids.
2. Lower cellular cholesterol content by increasing bile acid synthesis.
3. Increase LDL receptors in liver.
4. Rise in receptor-mediated endocytosis of LDL lowers plasma LDL levels.
5. Increase in cholesterol biosynthesis (bad).
6. Increase in plasma VLDL levels (bad) [do not use in patients with elevated VLDL]
7. Modest increase in HDL levels (10%) [good]

MAO of Resins and Statins

Beneficial Effects of Resins

Lower LDL levels about 15 to 25%
Increase HDL levels about 10%
Relatively safe drugs (no systemic absorption)
Good combo agents with statins
Decreases morbidity and mortality of CAD

Adverse Effects of Resins

Gritty bad taste, patients don’t like
Increase cellular cholesterol biosynthesis
Increase plasma VLDL levels (do not use in patients with ↑ VLDL, TGs).
GI: nausea, constipation, bloating (less with Colesevelam [Welchol])
Decreases absorption of other agents
- fat soluble vitamins A, D, E & K
- aspirin, thiazides, digoxin, phenobarbital

Statins - MOA

Statins: Fluvastatin, Rosuvastatin, Pravastatin, Lovastatin, Simvastatin and Atorvastatin.
1. Competitive inhibitors of HMG-CoA reductase which regulates cholesterol formation.
2. Decreased cellular cholesterol level increases LDL receptors.
3. Rise in receptor-mediated endocytosis of LDL lower plasma LDL levels. [15-50%]
4. Modest increase in HDL levels (10%)
5. Statins + Resins are good combination for lowering elevated LDL levels.
6. Atorvastatin and simvastatin also lower VLDL.
**Beneficial Effects of Statins**

- **Lower plasma LDL levels**, best agents (15 to 50%)
- **Increase plasma HDL levels** (10%)
- Atorvastatin & Simvastatin also lower plasma VLDL
- ComboRx with Resins to lower plasma LDL
- Reduce morbidity and mortality of CAD

**Statin Potency**

- Statin dose required to lower LDL 30 to 35%
  - Atorvastatin [10 mg] = Rosuvastatin [10 mg] >
  - Simvastatin [20 mg] < Pravastatin [40 mg] =
  - Lovastatin [40 mg] < Fluvastatin [80 mg]

- Atorvastatin and Rosuvastatin are most potent statins
- Best if taken evenings with food
**Ezetimibe - MOA**

1. Inhibits cholesterol absorption in intestinal cells.
2. Reduces cholesterol transport in intestinal cell wall.
3. Reduces cholesterol transport by more than 50%.
4. Reduces VLDL by about 5%.
5. Increases HDL by about 3%.
6. Ezetimibe enhances the lipid-lowering effects of statins.
7. In combination with statins enhances the reductions in LDL and VLDL. Less statin required to significantly lower LDL and VLDL (Now in question?).
8. Dosage: 10 mg oral dose alone or combo with statins.

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**Beneficial Effects of Ezetimibe**

- Reduces Plasma LDL (18%)
- Reduces Plasma VLDL (5%)
- Increases Plasma HDL (3%)

**Enhances the lipid-lowering effects of statins.**

No adverse effects identified (safe drug??)

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**Clinical Trials**

- **SHARP** (Study of Heart and Renal Protection)
- **SEAS** (Simvastatin and Ezetimibe in Aortic Stenosis)
- **ENHANCE** (Ezetimibe and Simvastatin in Hypercholesterolemia Enhances Atherosclerosis Regression)
- **IMPROVE IT** (Improved Reduction of Outcomes: VYTORIN Efficacy International Trial)

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**Clinical Studies**

- **ENHANCE** (Ezetimibe and Simvastatin in Hypercholesterolemia Enhances Atherosclerosis Regression) Vytorin vs Zocor
  - Endpoint plaque thickness. LDL ↓60%
  - Vytorin: 10.011 Zocor: 10.005

- **SHARP** (Study of Heart and Renal Protection)
  - 9,000 patients with chronic kidney disease. The study assesses the effect of Vytorin therapy on the time to the first major vascular event (i.e., heart attack, stroke, or revascularization)

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**Clinical Studies**

- **SEAS** (Simvastatin and Ezetimibe in Aortic Stenosis): 1900, Reduction in mortality/morbidity of patients with heart valve stenosis
  - Vytorin: 102/39 Placebo: 67/23

- **IMPROVE IT** (Improved Reduction of Outcomes: VYTORIN Efficacy International Trial): 10,000, Evaluate risk reduction by VYTORIN vs Zocor (simvastatin) in reducing death and major coronary events in patients with acute coronary syndromes
Niacin (Nicotinic Acid and Vitamin B3)

1. Decrease VLDL production by inhibiting adipose tissue lipolysis (main action).
2. Increase VLDL clearance by increasing LPL activity.
3. Lowers IDL and LDL production and content.
4. Increases HDL levels (20-50%) best agent for increasing HDL.
5. Lipoproteins: Lowers VLDL, IDL and LDL

Dose: 2-6 g oral dose given daily in divided doses (start low) with meals.

Beneficial Effects of Niacin

- Lowers Plasma VLDL (primary), IDL and LDL.
- Increases Plasma HDL (20 to 50%) [best HDL stimulator]
- Reduces morbidity and mortality of CAD

Adverse Effects of Niacin

- GI distress, facial and chest flushing (involves PG’s, reduced if aspirin taken just prior, now available as combo Rx), rashes and itching
- Potentiates gout (decrease uric acid secretion), diabetes and peptic ulcers
- May produce liver injury

Fibrates - MOA

Gemfibrozil, Fenofibrate, Clofibrate

1. Increase VLDL (TG’s) clearance by increasing LPL activity (best agent). Via activation of peroxisome proliferator activated receptor α (PPARα).
2. Decrease VLDL production by inhibiting adipose tissue lipolysis
3. Lowers IDL and LDL production and content.
4. Increase HDL levels (20-30%).
5. Lipoproteins: Lowers VLDL (TG’s), IDL and LDL.

Dosage: oral dose 1 to 2 times per day gemfibrozil (600 mg) fenofibrate (67 mg), fenofibrate is more potent than gemfibrozil.

Beneficial Effects of Gemfibrozil, Clofibrate & Fenofibrate

- Lower Plasma VLDL (primary), IDL and LDL.
- Greatest decrease in plasma TG’s (VLDL)
- Increase Plasma HDL (20 to 30%)
- Reduces morbidity and mortality of CAD
- Fenofibrate is more potent than Gemfibrozil
Adverse Effects of Fibrates

- GI distress (discomfort), rashes and headaches
- May produce liver injury
- Gemfibrozil potentiates myopathy with statins, combination should be avoided
- Fenofibrate is safer to use with statins
- May increase risk of gallstones

Lipid-Lowering Agents - Summary

<table>
<thead>
<tr>
<th></th>
<th>LDL</th>
<th>HDL</th>
<th>TGs</th>
<th>Notes</th>
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</thead>
<tbody>
<tr>
<td>Resins</td>
<td>↓</td>
<td>↑</td>
<td>↑</td>
<td>Hemat it, gritty, GI discomfort, constipation, ↑ LDL-Rec, ↑ VLDL, ↓ abs. fat sol. Vitamins</td>
</tr>
<tr>
<td>Statins</td>
<td>↓</td>
<td>↑</td>
<td>↓</td>
<td>Liver toxicity, myopathy, ↑ myelination CI, ↑ absorpt. fat sol. Vitamins, ↓ LDL-Rec</td>
</tr>
<tr>
<td>Niacin</td>
<td>↓</td>
<td>↑</td>
<td>↓</td>
<td>Flushed face (β-aspirin), GI, glucose intolerance, gout, liver toxicity, ulcer, diabetes</td>
</tr>
<tr>
<td>Fibrates</td>
<td>↓</td>
<td>↑</td>
<td>↓</td>
<td>Nausea, skin rash, headaches, ↑ statin myopathy, gallstones, ↑ LDL synthesis</td>
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<tr>
<td>Inh. Cholesterol absorp.</td>
<td>↓</td>
<td>↑</td>
<td></td>
<td>Newest class: No major adverse effects noted</td>
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</table>

Adult Treatment Guidelines (2001)

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<thead>
<tr>
<th></th>
<th>Desirable mg/dl</th>
<th>Borderline to high</th>
<th>High mg/dl</th>
<th>Notes</th>
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<tbody>
<tr>
<td>Total Cholesterol</td>
<td>&lt; 200</td>
<td>200-239</td>
<td>&gt; 240</td>
<td>High if &gt;160mg/dl with coronary disease or more than 2 risk factors</td>
</tr>
<tr>
<td>LDL Cholesterol</td>
<td>&lt; 130</td>
<td>130-159</td>
<td>&gt; 160</td>
<td>Optimal &lt;100mg/dl</td>
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<tr>
<td>HDL Cholesterol: Men</td>
<td>&gt; 40</td>
<td>&gt; 50</td>
<td>&gt; 60</td>
<td></td>
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<tr>
<td>HDL Cholesterol: Women</td>
<td>&gt; 40</td>
<td>&gt; 50</td>
<td>&gt; 60</td>
<td></td>
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<tr>
<td>Triglycerides</td>
<td>&lt; 120-150</td>
<td>120-199</td>
<td>&gt; 200</td>
<td></td>
</tr>
</tbody>
</table>

Risk Factors: age > 45 (male) and 55 (females), family history of early vascular disease or hyperlipidemia, current cigarette smoker, elevated BP, obesity, diabetes and low HDL

Who Should Be Treated With Drugs?

- LDL levels > 190 mg/dl and 0-1 risk factors.
- LDL levels > 160 mg/dl and 2 or more risk factors.
- CAD and LDL > 100 mg/dl.
- Higher risk factors, more aggressive treatment

Risk Factors:
- smoking
- obesity
- diabetes
- low HDL
- family history of early CAD
- hypertension
- age

Primary Hypertriglyceridemia

<table>
<thead>
<tr>
<th>↑ Lipoproteins</th>
<th>Diet</th>
<th>Drug</th>
<th>Drugs</th>
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</thead>
<tbody>
<tr>
<td>Chylomicrons</td>
<td>low fat</td>
<td>none</td>
<td>none</td>
</tr>
<tr>
<td>Chylomicrons</td>
<td>no alcohol</td>
<td>none</td>
<td>none</td>
</tr>
<tr>
<td>Chylomicrons</td>
<td>low fat, sugar, ↑ PUFA</td>
<td>Niacin</td>
<td>Fibrates</td>
</tr>
<tr>
<td>VLDL</td>
<td>low sugar &amp; fat</td>
<td>Niacin</td>
<td>Fibrates</td>
</tr>
<tr>
<td>IDL</td>
<td>low fat, ↑ PUFA</td>
<td>Niacin</td>
<td>Fibrates</td>
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</table>
Primary Hypercholesterolemia

<table>
<thead>
<tr>
<th>Lipoproteins</th>
<th>Diet</th>
<th>Drug</th>
<th>Drug Combination</th>
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</thead>
<tbody>
<tr>
<td>VLDL + LDL</td>
<td>Low fat</td>
<td>Fibrates</td>
<td>Statins + Ezetimibe</td>
</tr>
<tr>
<td>No Resins</td>
<td>↑PUFAs</td>
<td>Statins</td>
<td>Statins + NA/Fenb</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Niacin</td>
<td>Stat + Ezet + NA/FB</td>
</tr>
<tr>
<td>LDL</td>
<td>Low fat</td>
<td>Resins</td>
<td>Statins + Ezet/Fenof</td>
</tr>
<tr>
<td>No Gemfibrozil</td>
<td>↑PUFAs</td>
<td>Statins</td>
<td>Resins + NA/Fenof/Femifibrozil</td>
</tr>
<tr>
<td>with Statins</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LDL</td>
<td>Low fat</td>
<td>Fibrates</td>
<td>Niacin + Resins + Statins + NA/Fenfibrate</td>
</tr>
</tbody>
</table>

Quiz 1
A 48-year-old man has a family history of cardiovascular disease. Physical examination shows no abnormalities. Fasting serum lipid studies show:
- Cholesterol total: 185 mg/dl
- LDL-cholesterol: 140 mg/dl
- HDL-cholesterol: 26 mg/dl
- Triglycerides: 200 mg/dl

Which of the following agents is most appropriate?
A. Cholestyramine
B. Ezetimibe
C. Gemfibrozil
D. Fluvastatin
E. Niacin

Quiz 2
A 48-year-old woman has no major medical illness but a family history of cardiovascular disease. Fasting serum lipid studies show:
- Cholesterol total: 180 mg/dl
- LDL-cholesterol: 135 mg/dl
- HDL-cholesterol: 30 mg/dl
- Triglycerides: 245 mg/dl

Which of the following agents is most appropriate?
A. Cholestyramine
B. Ezetimibe
C. Gemfibrozil
D. Simvastatin
E. Niacin

Quiz 3
A 56-year-old woman comes to her physician because of pain and cramps in her thighs for 2-weeks. Three months ago pharmacotherapy was initiated for dyslipidemia. Physical examination shows muscle tenderness in the thigh. Laboratory studies show elevated levels of aspartate aminotransferase (AST) and alanine aminotransferase (ALT).

Which of the following was the most likely agent prescribed to treat her dyslipidemia?
A. Cholestyramine
B. Ezetimibe
C. Gemfibrozil
D. Simvastatin
E. Niacin

Quiz 4
A 46-year-old woman comes to her physician because of a 1-week history of a warm, tingling feeling over her face and chest. Two weeks ago pharmacotherapy was initiated for dyslipidemia.

Which of the following was the most likely agent prescribed to treat her dyslipidemia?
A. Cholestyramine
B. Ezetimibe
C. Gemfibrozil
D. Simvastatin
E. Niacin

Quiz 5
A 54-year-old woman has a family history of cardiovascular disease. Fasting serum lipid studies show:
- Cholesterol total: 225 mg/dl
- LDL-cholesterol: 180 mg/dl
- HDL-cholesterol: 25 mg/dl
- Triglycerides: 210 mg/dl

The physician commences pharmacotherapy with two agents to improve her lipid profile. Which drug combination is most appropriate for this patient?
A. Atorvastatin and Cholestyramine
B. Ezetimibe and Atorvastatin
C. Niacin and Atorvastatin
D. Niacin and Cholestyramine
E. Ezetimibe and Cholestyramine
F. Ezetimibe and Niacin