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M1 - Immunology, Winter 2008

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http://hdl.handle.net/2027.42/64939
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Arachidonic Acid Metabolites and Inflammation

Joseph Fantone, M.D.
Host Defense 2/12  10-11:00am
INFLAMMATORY MEDIATORS

PLASMA DERIVED
• COMPLEMENT CASCADE
  C3a, C5a
• COAGULATION CASCADE
  Thrombin, plasmin

CELL-DERIVED
• VASOACTIVE AMINES
  histamine, serotonin
• OXYGEN METABOLITES
  hydrogen peroxide (H₂O₂)
  superoxide anion (O₂⁻)
  hypochlorous acid (HOCl⁻)
• ARACHIDONIC ACID METABOLITES
  cyclooxygenase-derived
  lipoxygenase-derived
• CYTOKINES
  Interleukins
  Chemokines
  Interferons
  Tumor Necrosis Factor
  Growth Factors
Intended Learning Outcomes: To Understand The

- Primary inflammatory mediators derived from the metabolism of arachidonic acid including their primary cellular source and biological activity.

- Effects of nonsteroidal anti-inflammatory compounds on blocking the production of arachidonic acid metabolites during disease.

- Mechanism of aspirin therapy and diets rich in fish containing high levels of omega 3 fatty acids as potentially important in lowering the incidence of cardiovascular disease.
YOU ARE WHAT YOU EAT
Arachidonic acid

**Phospholipid**

- **Phospholipase A**
  - Lysophospholipid
  - + Arachidonic acid

- **Phospholipase C**
  - Arachidonic acid
  - + phosphoryl-R

- Diacylglycerol
  - Diacylglyceride lipase

- Arachidonic acid + HO-CH
  - CH-CH
  - CH-CH

**Cyclooxygenase 1 + Lipoxygenase Products**
**Cyclooxygenase 2**
Leukotriene Synthesis

Arachidonic Acid

5-HPETE

Leukotriene A (LTA)

Leukotriene B (LTB)

Leukotriene C (LTC)

Leukotriene D (LTD)
# CELL DEPENDENT END-PRODUCT SPECIFICITY OF ARACHIDONIC ACID-DERIVED PRODUCTS

<table>
<thead>
<tr>
<th>CELL</th>
<th>PRODUCT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neutrophils</td>
<td>Leukotrienes</td>
</tr>
<tr>
<td>Macrophage/Monocyte</td>
<td>Prostaglandins +</td>
</tr>
<tr>
<td></td>
<td>Leukotrienes</td>
</tr>
<tr>
<td>Platelets</td>
<td>Thromboxoxane</td>
</tr>
<tr>
<td>Endothelial Cells</td>
<td>Prostacycllin</td>
</tr>
</tbody>
</table>
Biological Function

**Cyclooxygenase-derived Products:**

- **Prostaglandin E₂/Prostacyclin**
  - Immunoregulatory
  - Inhibits immune cell activation
  - Inhibits cytokine production
  - Inhibits mast cell activation
  - Blocks platelet aggregation
  - Increases vasodilation
  - Stimulates adenylate cyclase

- **Thromboxane**
  - Causes vasoconstriction
  - Induces platelet aggregation
Biological Function

**Lipoxygenase-derived Products:**

- Leukotriene B$_4$
  - Neutrophil Activation
  - degranulation

- Mast cell activation
  - degranulation

- Leukotriene C,D,E (SRS-A)
  - Causes smooth muscle contraction
  - Increases vascular permeability
In Vivo Effects of Arachidonic Acid Derived Products

• Regulates Thermostatic Set Point (Fever)
• Regulates Pain (Interacts with pain receptors)
• Regulates Blood Flow
• Regulates Leukocyte Activity
Hypothalamus

Production of Fever

Viruses
Bacteria
Toxins

Phagocytic leukocytes

Activated leukocytes → Endogenous pyrogen

Arachidonic Acid → Prostaglandin E2 → Temperature

Aspirin
NSAIDs

(e.g. Interleukin-1)

Shivering
Sweating
Vasomotor tone
Rheumatoid Arthritis distorts joints

Source: http://www.nih.gov/
Chemotactic Activity of LTB4

BY: Greg Luerman

GNU 1.2
Pharmacologic Regulation of Arachidonic Acid-Derived Products

• Modulate Phospholipase activity:
  – Suppress the release of arachidonic acid (no substrate available)
  – Blocks both COX and LO-derived products

• Modulate Cyclooxygenase Activity:
  – Blocks Cyclooxygenase-derived products
  – COX-1 and COX-2 inhibitors

• Modulate specific enzymes down-stream from COX:
  – Thromboxane synthetase inhibitors

• Modulate lipooxygenase activity:
  – Block 5-lipooxygenase enzyme
  – Small molecule receptor antagonists for cysteinyi leukotrienes
Non-Steroidal Anti-Inflammatory Compounds

- Aspirin (acetylsalicylic acid)
- Ibuprofen (propionic acid derivatives)
- Indomethacin (indole derivatives)
- Tylenol (Acetaminophen)
- COX-2 Inhibitors (Vioxx, celebrex, Bextra)
COX-2 Inhibitors

- **CELEBREX** (Celecoxib) Pfizer-(Pharmacia)
- **BEXTRA** (Valdecoxib) Pfizer
- **VIOXX** (Rofecoxib) Merck

Osteoarthritis
Rheumatoid arthritis
Primary dysmenorrhea
Pain management
Complications!!
INHIBITS CYCLO-OXYGENASE ENZYME IRREVERSIBLY BY ACETYLATING THE ENZYME AT THE ACTIVE SITE, THUS THE PRODUCTION OF ENDOPEROXIDES AND THEIR DERIVATIVES, INCLUDING PROSTAGLANDINS, THROMBOXANES, AND PROSTACYCLINS WILL BE INHIBITED.
Both inhibit cyclo-oxygenase activity by binding reversibly to the active site of the enzyme, thus blocking the formation of prostaglandins, thromboxanes, and prostacyclins.
AN ASPIRIN A DAY

Roughly 80 million aspirin tablets are consumed daily in the USA. Of those:
72% are taken for disease prevention
28% are taken for pain
Reduce the risk of heart attack or stroke with......
Thrombus Formation

Elastic Lamina

Injury

ADP

Thromboxane

Collagen

Aggregation

Platelets

Endothelium

Basement Membrane

Organization

Plaque
Can Aspirin Act As An Anti-thrombogenic Agent?

- Inhibits platelet aggregation by blocking platelet-derived thromboxane production

- Blocks platelet cyclooxygenase for the life of the platelet, as no new protein synthesis occurs

- Blocks endothelial cell-derived prostacyclin

- Suppression of endothelial cell-derived prostacyclin is short lived as endothelial cells can generation new cyclooxygenase enzyme

- Platelet activity is blocked more than endothelial cell activity
COX-2 inhibitors work by blocking COX-2 enzyme which is involved in the inflammation pathway. By sparing COX-1 gastrointestinal toxicity is reduced.

Physiologic Stimuli → COX-1 (constitutive) → PG E₂ (Renal function) → Thromboxane A₂ (Platelet function) → Prostacycline (PGL₂) (Gastric Protection) → COX-2 (inducible) → Pro-inflammatory PGs and other inflammatory mediators → Inflammation → Inflammatory Stimuli
lipid mediators of Inflammation

Stimulus

Phospholipase

Cell membrane
Phospholipids

Arachidonic acid
Acute inflammation: lipid mediators

Stimulus

Phospholipase

Phospholipids

Arachidonic acid

Cell membrane

COX-1+2

Prostaglandins

Prostaglandin E$_2$

Prostacyclin PGI$_2$

COX-1

Thromboxanes

TXB$_2$

Lipooxigenases (5-LO)

Leukotrienes

LTB$_4$

LTC$_4$, LTD$_4$
Acute inflammation: lipid mediators

Stimulus

Phospholipase

Cell membrane
Phospholipids

Arachidonic acid

COX-1+2
Prostaglandins
Prostaglandin E$_2$
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COX-1
Thromboxanes
TXB$_2$

Lipooxigenases (5-LO)
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LTC$_4$, LTD$_4$

Acute inflammation: lipid mediators

An important role in vascular homeostasis

- **Endothelium**
  - Prostacyclin $\text{PGI}_2$
  - Anti-thrombotic

- **Platelets**
  - TXB2
  - Pro-thrombotic
Acute inflammation: lipid mediators

Endothelium

- COX-2
- Prostacyclin PGI$_2$
- Anti-thrombotic

Platelets

- COX-1
- TXB2
- Pro-thrombotic

Therapeutic targets:

- NSAIDs inhibit both COX-1 and COX-2;
- COXIBs inhibit COX-2
Acute inflammation: lipid mediators

**Therapeutic targets**

**Endothelium**

- COX-2

  - Prostacyclin PGI$_2$

  - Anti-thrombotic

**Platelets**

- COX-1

  - TXB2

  - Pro-thrombotic

* Classical NSAID, it inhibits both COX enzymes
Acute inflammation: lipid mediators

Endothelium
- COX-2
- Prostacyclin PGI₂
  - Anti-thrombotic

Platelets
- COX-1
- TXB2
  - Pro-thrombotic

Therapeutic targets
- Vioxx®
- TXB2
Acute inflammation: lipid mediators

**Therapeutic targets**

**Endothelium**
- Aspirin inhibits COX-2 irreversibly
  - Prostacyclin PGI₂

**Platelets**
- Aspirin inhibits COX-1 irreversibly
  - TXB₂

All cells but the platelet can resynthesize the enzymes.
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  Growth Factors