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- I have no disclosures to report related to this presentation.
- I serve on the Research Board for Produce for Better Health
- I serve as consulting faculty for the CDR Adult Weight Management certificate program

Learning Objectives
Suggested Learning Codes: 2110, 4040, 4050, 5150
Suggested Performance Indicators: 8.1.4, 8.1.5, 8.1.3

1. Describe the physiology of the relationship between inflammation and cancer.
3. Identify common biochemical indices used to assess inflammation and their relationship to cancer and cancer prognosis.
4. Evaluate and interpret current epidemiological and clinical evidence linking inflammation, diet and cancer.
5. Translate current evidence into nutritional counseling/care plans for cancer risk reduction.
BACKGROUND

Rudolf Virchow (Father of Pathology)
- First to link inflammation to cancer
- "Lymphoreticular infiltration" of cancer reflects the origin of cancer at sites of inflammation (1863)

Carcinogenesis
Classic Hallmarks
- Self-sufficiency in growth signals
- Insensitivity to anti-growth signals
- Inflammatory microenvironment
- Tissue invasion & metastasis
- Limitless replicative potential
- Sustained angiogenesis
- Evading apoptosis

Emerging Hallmarks
- Avoiding immune destruction
- Tumor-promoting inflammation
- Genome instability and mutation
- Deregulating cellular energetics

INFLAMMATION
Inflammation and the Cancer Continuum

- Chronic inflammation, Infection, Autoimmunity
- Tumor-associated inflammation
- Therapy-induced inflammation
- Inflammation caused by environmental and dietary exposure


Inflammatory Conditions and Tumorigenesis

<table>
<thead>
<tr>
<th>Pathogenic Condition</th>
<th>Associated Neoplasm</th>
<th>Aetologic Agent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silicosis</td>
<td>Lung, mesotheloma</td>
<td>Asbestos</td>
</tr>
<tr>
<td>Bronchitis</td>
<td>Lung</td>
<td>Tobacco</td>
</tr>
<tr>
<td>Cystitis</td>
<td>Bladder</td>
<td>Catheters</td>
</tr>
<tr>
<td>Gingivitis</td>
<td>Oral squamous cell</td>
<td>Poor dental hygiene</td>
</tr>
<tr>
<td>IBD, Crohn’s, UC</td>
<td>Colorectal</td>
<td>Ulceroma</td>
</tr>
<tr>
<td>Chronic pancreatitis</td>
<td>Pancreatic</td>
<td>Alcoholism</td>
</tr>
<tr>
<td>Reflux esophagitis</td>
<td>Esophageal</td>
<td>Gastric acids</td>
</tr>
<tr>
<td>Skin inflammation</td>
<td>Melanoma</td>
<td>UV light</td>
</tr>
</tbody>
</table>


Tumorigenesis

- Tumor microenvironment assoc with oxidative stress response; cancer cells can be responsive to ER stress
- ER stress leads to migration and aggregation of immune cells with the tumor area
- In turn, tumor-promoting cytokines are stimulated and released in the surrounding tissues and systemically
- Acute-phase proteins also are activated to combat tumor growth
- As are dendritic cells which migrate to tumor in a secondary immune-centric effort to combat tumor growth
Tumorigenesis & Inflammation: Early research

- Chronic, sub-clinical inflammation may increase cancer risk
- Basic mechanistic studies in animal and cell culture models demonstrate the role of inflammatory molecules in colon tumorigenesis and metastasis
- Inflammation shown to induce reactive oxygen species and promote DNA damage (genotoxicity)
- Numerous studies reporting on regular use of aspirin and reduced risk of cancers (e.g., colorectal, ovarian, melanoma, breast)
- The inducible form of the prostaglandin-endoperoxide synthase 2 or cyclooxygenase 2 enzyme shown to be overexpressed in a number of cancers and to be inhibited by COX2 specific drugs (celecoxib, rofecoxib)

Double-Hit: Infection and Inflammation

- Risk for several cancers is elevated in the presence of viruses
  - HPV- cervical
  - H pylori- gastric
  - EBV- nasopharyngeal
  - Hepatitis B, C – liver cancer
- Pathogens promote inflammation-associated immune response
- Elevated cytokines
  - Tumor growth factors
  - TSG and oncogene expression
  - Govern T-helper cell, NK cells, T regulatory cells, and Th17 cells
- Further compounded by aging immune response
Tumor-associated Inflammation and Prognosis: Meta-analysis for Colorectal Cancer

- Inflammation within the host systemically is associated with greater risk for many cancers
- Inflammation within the tumor may be a necessary response to combat disease progression
- Meta-analysis: 30 studies, 2988 patients with CRC

Results:
- Tumor-specific inflammation assoc with 41% higher overall and 60% cancer-specific survival
- High CD8+ cells within stroma; high CD4+3+ in invasive tumor margins assoc with improved survival


Interplay with the Gut Microbiome

Intestinal Microbiome

Inflammation

Diet

Bacterial Toxins

Physical Activity

COLORECTAL CANCER

Inter-related Mechanistic Targets for Dietary Components and Pharmaceuticals

Adapted from Ford NA et al. Frontiers in Oncology, 2013
Summary

- Inflammation is a hallmark of cancer
- Strong evidence exists to support a role for inflammation in cancer development and progression
- Pathogens and related or unrelated inflammation may further exacerbate risk
- Targeted approaches to reduce inflammation hold promise to reduce cancer risk

Interplay of Diet-Obesity-Inflammation and Cancer
Adipocyte and Inflammation

CD4+ regulatory T cell
CD8+ effector T cell
M2 macrophage
M1 macrophage
Vessels
Dead adipocyte

Adipocyte stromal cells have high concentrations of immune cells and angiogenic potential and as such may contribute to cancer progression


Obesity-associated Chemoresistance:
Primary Role of Inflammation

- Metabolic perturbations
- Impaired drug delivery
- Chronic low-grade inflammation
- Adipose tissue expansion
- Altered pharmacokinetics
- Increased tumor-associated microphages

Inflammation-associated Biomarkers and Cancer

<table>
<thead>
<tr>
<th>Biomarker</th>
<th>Role</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insulin</td>
<td>Growth-promotion, cell division, anti-apoptotic</td>
</tr>
<tr>
<td>IGF-1 and IGF-BP-1</td>
<td>Increased cell migration, prolonged elevated insulin, potentiates growth factors</td>
</tr>
<tr>
<td>C-reactive protein (CRP)</td>
<td>Inflammation, may correlate with estradiol</td>
</tr>
<tr>
<td>Interleukin 6</td>
<td>Inflammation, growth and differentiation of malignant cells</td>
</tr>
<tr>
<td>Tumor necrosis factor alpha</td>
<td>Inflammation, associated with insulin resistance</td>
</tr>
<tr>
<td>Serum amyloid A (SAA)</td>
<td>Low-grade, chronic inflammation</td>
</tr>
<tr>
<td>NF-kB signaling</td>
<td>Transcription factor family associated with immunity and inflammation</td>
</tr>
</tbody>
</table>

Cytokines and Cancer Prognosis: Examples

- IL-6 – elevated in tumor, serum and peritoneal fluid of ovarian cancer patients (Coward and Kulbe, 2012)
- C-Reactive protein/albumin ratio predicts survival in hepatocellular cancer (Kinoshita et al, 2015)
- IL-6 associated with lung cancer mortality in Blacks and NHW; IL-10 associated with increased survival in Blacks (Enewold et al, CEBP, 2009)
- Macrophage infiltration has been associated with angiogenesis and prognosis in women presenting with breast cancer (Leek RD et al, Cancer Res, 1996)
Inflammation and Cancer Prognostic Scores: The Glasgow Prognostic Index

<table>
<thead>
<tr>
<th>Dynamic inflammatory based prognostic score</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>C-reactive protein ≤ 10 mg/l and albumin ≥ 35 g/l</td>
<td>0</td>
</tr>
<tr>
<td>C-reactive protein ≤ 10 mg/l and albumin &lt; 35 g/l</td>
<td>0</td>
</tr>
<tr>
<td>C-reactive protein &gt; 10 mg/l and albumin ≥ 35 g/l</td>
<td>1</td>
</tr>
<tr>
<td>C-reactive protein &gt; 10 mg/l and albumin &lt; 35 g/l</td>
<td>1</td>
</tr>
<tr>
<td>Platelet count/lymphocyte count &gt; 300:1</td>
<td>2</td>
</tr>
<tr>
<td>Platelet count/lymphocyte count 300-160:1</td>
<td>1</td>
</tr>
<tr>
<td>Platelet count/lymphocyte count 160-50:1</td>
<td>1</td>
</tr>
<tr>
<td>Platelet count/lymphocyte count 50 or less</td>
<td>0</td>
</tr>
<tr>
<td>Neutrophil count/lymphocyte count ≥ 5:1</td>
<td>0</td>
</tr>
<tr>
<td>Neutrophil count/lymphocyte count &lt; 5:1</td>
<td>0</td>
</tr>
<tr>
<td>White cell count ≤ 11 x 10⁹/l and C-reactive protein ≤ 10 mg/l</td>
<td>0</td>
</tr>
<tr>
<td>White cell count &gt; 11 x 10⁹/l and C-reactive protein ≤ 10 mg/l</td>
<td>1</td>
</tr>
<tr>
<td>White cell count &gt; 11 x 10⁹/l and C-reactive protein &gt; 10 mg/l</td>
<td>2</td>
</tr>
</tbody>
</table>

GPS associated with:
- Undesirable weight loss
- Loss of muscle mass
- Higher comorbidity
- Increased pro-inflammatory cytokines
- Increased angiogenesis
- High prognostic value in cancer

The GPS: CRP, Albumin and the Ratio:
Pretreatment Measures Predict Survival in Hepatocellular Cancer

- 186 hepatocellular carcinoma patients
- Evaluated CRP/albumin ratio at the time of diagnosis
- Ratio above 0.037 was associated with progressive disease
- Performed better/predicted survival more accurately than Glasgow prognostic score, and neutrophil lymphocyte ratio
- More recent report suggests CRP independently predicts prognosis in HCC patients

Inflammation, Diet and Survival

- CRP and inflammation overall is associated with poorer survival (AlMurri et al, 2006; breast); Jamieson et al, 2005 (pancreas); Lamb, 2006 (renal clear cell); Crozier et al, 2006 (CRC)).
- Inflammation is pathogenic in cancer-associated malnutrition (Argiles et al, 2003).
- Malnutrition is associated with higher mortality in patients with cancer (AND Evidence Analysis Library).
- Malnutrition, including hypoalbuminemia, in patients with cancer is commonly responsive to MNT.
Summary

- Several cytokines have been implicated in relation to cancer risk and prognosis
- Obese individuals commonly present with chronic, low-grade inflammation expressing many of the cytokines also associated with cancer risk
- The combination of obesity and infection may further exacerbate risk for select cancers
- Dietary modification, including weight management and/or MNT targeting low albumin, may attenuate inflammatory response and in turn modify cancer risk and/or survival

DIET-DERIVED INFLAMMATION

Fatty Acids

<table>
<thead>
<tr>
<th>Omega 6</th>
<th>Omega 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn-fed animal products, oil-based salad dressings</td>
<td>Fish, walnuts, seeds, dark leafy greens, grass-fed animal products</td>
</tr>
</tbody>
</table>

Effecting enzymes of metabolism:

- Cyclooxygenase (COX)
- Lipoxygenase (LOX)
- Cytochrome P450 (CYP)

Which in turn induce the activity of:

- Thromboxanes
- Prostaglandins
- Leukotrienes
- Epoxyeicosatrienoic acid

Sodium and Inflammation

- Sodium intake remains high in US adults
- High sodium/salt intake has been associated with inflammation
- Limited study of sodium intake and cancer

Zhang WC et al., Cell Res, 2015

Advanced Glycation End-products & Inflammation

- AGE abundant in diet: N-Carboxymethyllysine (CML)
  - Proteins
  - Saturated fats
  - Red meat, white meats, processed meats
  - High temperature cooking
- Mechanistically associated with oxidative stress (lipid peroxidation), insulin resistance and inflammation
- AGE intake has been associated with pancreatic cancer in men (AARP study)
- Study of 24 adults randomized to high vs low AGE diet for 6 weeks showed no change in exposure or inflammation (IL-6, CRP, TNF-αR)


Dietary Patterns and Inflammatory Biomarkers

- Systematic Review: Barbaresko et al, ILSI, 2013
- 46 studies, representing 70,659 study participants
- 95% diet data estimated by Food Frequency Questionnaire
- Most common food choices were associated with elevated CRP
- Eating patterns associated with inflammation included: beer, red and processed meats.
- IL-6 associated with sweet and dessert pattern as well as high-fat dairy and red meat, alcohol patterns
DIET-DERIVED ANTI-INFLAMMATORY EFFECTS

Anti-inflammatory Modulating Dietary Components

- Allicin - onions
- Catechins - green tea
- Cinnamaldehyde - cinnamon
- Curcumin - turmeric
- Lycopene - tomato products, watermelon
- Omega-3 fatty acids
- Polyphenols - tea, berries
- Resveratrol - grapes
- Sulforaphane and di-indolylmethane - broccoli/cruciferae


Anti-inflammatory, Mediterranean Diet

- Observational and interventional evidence for anti-inflammatory effects of MED pattern
- Some epidemiological evidence to support lower cancer risk
- RCT lacking in terms of cancer survival

MED Diet and Inflammation

<table>
<thead>
<tr>
<th>Author</th>
<th>Sample, Country</th>
<th>Duration</th>
<th>Change in Biomarker</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bluher</td>
<td>109, Israel</td>
<td>2 y</td>
<td>↓ CRP and MCP-1</td>
</tr>
<tr>
<td>Konstantinidou</td>
<td>60, Spain</td>
<td>3 mo</td>
<td>↓ CRP, ↓P-selectin, ↔ MCP-1</td>
</tr>
<tr>
<td>Esposito</td>
<td>90, Italy</td>
<td>Cross-sectional</td>
<td>↓ CRP, IL-6, IL-18</td>
</tr>
<tr>
<td>Azini</td>
<td>131, Italy</td>
<td>Cross-sectional</td>
<td>↑ IL-10, ↑TNFα</td>
</tr>
<tr>
<td>Carter</td>
<td>13,197, USA</td>
<td>Cross-sectional</td>
<td>↓ CRP, ↑fibrinogen</td>
</tr>
<tr>
<td>Dedoussis</td>
<td>957, France, Italy, Poland, Germany</td>
<td>Cross-sectional</td>
<td>↓ IL-8, ↔ MCP-1, CRP and TNFα</td>
</tr>
<tr>
<td>Panagiotakos</td>
<td>3042, Greece</td>
<td>Cross-sectional</td>
<td>↓ CRP and fibrinogen</td>
</tr>
<tr>
<td>Fung</td>
<td>660 women, USA</td>
<td>Cross-sectional</td>
<td>↓ CRP, IL-6, E-selectin, VCAM-1, ↔ ICAM-1</td>
</tr>
</tbody>
</table>


Dietary Inflammatory Index

- A composite score was needed to estimate overall inflammatory effect of a multi-component diet that includes pro and anti-inflammatory foods.
- 6500 peer-reviewed manuscripts were reviewed that evaluated one or more dietary components and one or more inflammatory indices
- International with standardization to global referent values in assigning inflammatory / anti-inflammatory potential
  - Maximum pro-inflammatory diet score: +7.98
  - Maximum anti-inflammatory score: -8.87
- Associated with hs CRP (Shivappa et al, PHN, 2013)

Sample Foods and Inflammatory Score

<table>
<thead>
<tr>
<th>Foods / Dietary Component</th>
<th>Overall Inflammatory Effect Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alcohol</td>
<td>-0.278</td>
</tr>
<tr>
<td>B-carotene</td>
<td>-0.584</td>
</tr>
<tr>
<td>Fiber</td>
<td>-0.663</td>
</tr>
<tr>
<td>Garlic</td>
<td>-0.412</td>
</tr>
<tr>
<td>Isoflavones</td>
<td>-0.593</td>
</tr>
<tr>
<td>N-3 fatty acids</td>
<td>-0.436</td>
</tr>
<tr>
<td>Onion</td>
<td>-0.310</td>
</tr>
<tr>
<td>Tea</td>
<td>-0.536</td>
</tr>
<tr>
<td>Tumeric</td>
<td>-0.785</td>
</tr>
<tr>
<td>Vitamin C</td>
<td>-0.424</td>
</tr>
<tr>
<td>Vitamin D</td>
<td>-0.446</td>
</tr>
<tr>
<td>Energy</td>
<td>+0.180</td>
</tr>
<tr>
<td>Fat</td>
<td>+0.298</td>
</tr>
<tr>
<td>Saturated fat</td>
<td>+0.373</td>
</tr>
</tbody>
</table>

Adapted from Shivappa et al, PHN, 2013
Construct Validation

Association between quintiles of the FFQ-derived DII and biomarkers of inflammation

**SEASONS study**
- Higher DII score associated with > risk for hsCRP above 3mg/dl
- OR\textsubscript{adjusted} 1.10 (1.02-1.19) using 7 day diet records

**Asklepios study**
- Higher DII score associated with > risk for IL-6 above 1.6 pg/ml
- OR\textsubscript{adjusted} 1.19 (1.04-1.36)

- Head and neck cancer patients (n=160): whole foods diet associated with lower IL-6, TNFα and IFN-γ

Models adjusted for age, body mass index, race/ethnicity, educational level, smoking status, physical activity, use of NSAIDs, statins, inflammation-related co-morbidities (history of inflammatory disease, cancer stage)


<table>
<thead>
<tr>
<th>Food group (medium servings/day)</th>
<th>Q1 (&lt;7.055, &lt;3.136) (healthiest)</th>
<th>Q2 (7.055-&lt;9.95)</th>
<th>Q3 (9.95-&lt;12.86)</th>
<th>Q4 (12.86-&lt;15.77)</th>
<th>Q5 (15.77-5.636) (least healthy)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fruits</td>
<td>2.71</td>
<td>2.94</td>
<td>1.85</td>
<td>1.73</td>
<td>1.73</td>
</tr>
<tr>
<td>Vegetables</td>
<td>3.15</td>
<td>2.30</td>
<td>2.12</td>
<td>2.00</td>
<td>2.00</td>
</tr>
<tr>
<td>Combo Fruit/Veg</td>
<td>5.86</td>
<td>4.34</td>
<td>3.97</td>
<td>3.73</td>
<td>3.73</td>
</tr>
<tr>
<td>Fish</td>
<td>0.97</td>
<td>0.97</td>
<td>0.97</td>
<td>0.97</td>
<td>0.97</td>
</tr>
<tr>
<td>Red meat</td>
<td>0.63</td>
<td>0.73</td>
<td>0.74</td>
<td>0.76</td>
<td>0.76</td>
</tr>
<tr>
<td>Poultry</td>
<td>0.44</td>
<td>0.40</td>
<td>0.38</td>
<td>0.38</td>
<td>0.38</td>
</tr>
<tr>
<td>Soy</td>
<td>0.08</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
</tr>
<tr>
<td>Nuts</td>
<td>0.26</td>
<td>0.20</td>
<td>0.18</td>
<td>0.17</td>
<td>0.17</td>
</tr>
<tr>
<td>Combo Nut/soy</td>
<td>0.34</td>
<td>0.22</td>
<td>0.20</td>
<td>0.18</td>
<td>0.18</td>
</tr>
<tr>
<td>Grains</td>
<td>5.89</td>
<td>4.69</td>
<td>4.55</td>
<td>4.47</td>
<td>4.47</td>
</tr>
<tr>
<td>Whole Grain</td>
<td>1.73</td>
<td>1.24</td>
<td>1.17</td>
<td>1.12</td>
<td>1.12</td>
</tr>
<tr>
<td>Milk</td>
<td>0.97</td>
<td>0.88</td>
<td>0.80</td>
<td>0.71</td>
<td>0.71</td>
</tr>
<tr>
<td>Dairy</td>
<td>2.30</td>
<td>2.06</td>
<td>1.92</td>
<td>1.76</td>
<td>1.76</td>
</tr>
</tbody>
</table>

**Mean DII Scores Across Years of Follow-up in the DMT**

P-value for the difference in DII scores between intervention and control was 0.62 at baseline, and <0.0001 for each year from year 1 onwards

Courtesy of Susan Steck, USC Cancer Center
Breast Cancer Incidence and Mortality Across DII Tertiles

<table>
<thead>
<tr>
<th></th>
<th>T1 (-7.05, -2.37) (healthiest)</th>
<th>T2 (-2.37, -0.47)</th>
<th>T3 (0.47, 5.79) (least healthy)</th>
<th>P_trend</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breast cancer cases, n=1922</td>
<td>2155</td>
<td>1912</td>
<td>1774</td>
<td></td>
</tr>
<tr>
<td>Breast cancer, HR (95%CI)*</td>
<td>1.00 (ref)</td>
<td>0.95 (0.89, 1.01)</td>
<td>0.99 (0.92, 1.06)</td>
<td>0.89</td>
</tr>
<tr>
<td>HER2+ cases, n=662</td>
<td>215</td>
<td>222</td>
<td>225</td>
<td></td>
</tr>
<tr>
<td>HER2+ cancers, HR (95%CI)*</td>
<td>1.00 (ref)</td>
<td>1.12 (0.92, 1.35)</td>
<td>1.29 (1.05, 1.59)</td>
<td>0.01</td>
</tr>
<tr>
<td>Breast cancer mortality</td>
<td>117</td>
<td>136</td>
<td>153</td>
<td></td>
</tr>
<tr>
<td>Breast cancer mortality, HR (95%CI)*</td>
<td>1.00 (ref)</td>
<td>1.06 (0.81, 1.37)</td>
<td>1.30 (0.99, 1.71)</td>
<td>0.04</td>
</tr>
</tbody>
</table>

*Adjusted for age, race/ethnicity, body mass index, physical activity, education, smoking status, mammography within 2 years of baseline, age at menarche, number of live births, oophorectomy status, hormone therapy use, NSAID use, dietary modification trial arm, hormone therapy trial arm, calcium and vitamin D trial arm, total energy intake, estrogen receptor status, progesterone receptor status, stage and time since diagnosis.

Patterns of Change in DII and Breast Cancer Risk

<table>
<thead>
<tr>
<th></th>
<th>Anti-inflammatory stable</th>
<th>Anti-inflammatory change</th>
<th>Neutral inflammation stable</th>
<th>Pro-inflammatory stable</th>
<th>Pro-inflammatory change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Triple-negative (ER−, PR−, HER2−)</td>
<td>1.00 (ref)</td>
<td>0.91 (0.83, 0.99)</td>
<td>0.99 (0.92, 1.10)</td>
<td>0.65 (0.65, 0.86)</td>
<td></td>
</tr>
<tr>
<td>ER−, PR−, HER2+ subtype</td>
<td>1.00 (ref)</td>
<td>1.14 (1.07, 1.22)</td>
<td>1.02 (0.99, 1.05)</td>
<td>0.99 (0.99, 1.05)</td>
<td></td>
</tr>
<tr>
<td>Luminal A (ER+ and/or PR+, HER2−)</td>
<td>1.00 (ref)</td>
<td>0.92 (0.81, 1.10)</td>
<td>1.03 (0.89, 1.19)</td>
<td>0.98 (0.77, 1.21)</td>
<td></td>
</tr>
<tr>
<td>Luminal B (ER+ and/or PR+, HER2+)</td>
<td>1.00 (ref)</td>
<td>0.92 (0.59, 1.43)</td>
<td>0.84 (0.51, 1.35)</td>
<td>0.92 (0.61, 1.37)</td>
<td></td>
</tr>
</tbody>
</table>

All models were adjusted for age, race/ethnicity, education, smoking status, physical activity, body mass index, NSAID use, category and duration of estrogen use, category and duration of estrogen & progesterone use, and total energy intake.

Courtesy of Susan Steck, USC Cancer Center

DII and Cancer Risk Associations

- WHI prospective study of colorectal cancer risk
- Iowa Women’s Health Study and CRC risk
  - Colon: HRate-adj Continuous: 1.08 (1.02-1.13); Categorical 1.26 (1.08-1.53)
  - Rectal: HRate-adj 1.13 (0.98-1.31)
- Higher risk in the Bellvitge case-control analysis
  - Colorectal: OR 1.66 (1.08-2.56); Colon: OR 2.24 (1.33-3.77)
- Italian case-control studies of pancreatic cancer and separately prostate cancer risk also show elevated risk of 24% and 33%, respectively

DII and Length of Stay: CRC Surgery

- 689 patients undergoing surgical resection of colon for cancer in Krakow, Poland
- FFQ by interview prior to surgery, on admission to hospital
- Mean hospitalization: 10.9 (9.4) days
- Overall linear regression showed inverse association (b=0.59)
- The effect was driven by patients under age 60 y
- Higher DII score is associated with 39% reduction in mortality in patients with distant metastatic disease

Galas, Kulig and Kulig, EJCN, 2014; Galas and Kulig, J Cancer Res Clin Oncol, 2014

EVIDENCE

Role of Weight Loss in Reducing Inflammation

- 218 healthy, overweight, non-obese adults
- 25% caloric restriction; 10.4% weight loss over 24 months
- Significant decline in CRP, ICAM-1 and TNF-α with caloric restriction
- WBC and total lymphocytes also lowered during intervention as compared to ad lib diet
- Cell-mediated immunity was not compromised (delayed hypersensitivity antibody response testing)

Meydani SN et.al., Aging, July, 2016
Nutrition, Exercise and Women Study

- Ancillary study designed to test effect of modest weight loss on inflammatory markers
- 503 (439 completers) overweight/obese, post-menopausal women
- Diet, exercise or combination x 12 months
- 5% weight loss was associated with significant reductions in CRP, IL-6 and SAA with diet or diet + exercise
- Similarly a trial by Nicklas et al associated w 5.7% loss in BW with reduced inflammatory cytokine levels (AJCN, 2004)
- Reviews suggest consistent reduction in inflammatory markers with weight loss interventions


Weight Loss and Inflammatory Response in Breast Cancer Survivors

- 50 overweight breast cancer survivors on Tamoxifen® or aromatase inhibitors
- Randomized, 2-arm trial (Low fat or Low carbohydrate)
- Face-to-face counseling with a dietitian weekly x 4 weeks, then monthly for 5 months
- Baseline, 3 and 6 month measures of:
  - Anthropometrics, body composition
  - Metabolic indices
  - Inflammation (CRP)


Results

<table>
<thead>
<tr>
<th>Changes in Inflammatory/ Metabolic Indices</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean weight loss 6.1 kg @ 6 months</td>
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<tr>
<td>Significant reduction in insulin, s.</td>
</tr>
<tr>
<td>cholesterol/LDL cholesterol, TGL (low CHO)</td>
</tr>
<tr>
<td>hsCRP reduced by -0.4 (p &lt;0.06)</td>
</tr>
<tr>
<td>Study of 68 overweight breast cancer</td>
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<tr>
<td>survivors showed reductions in IL-6 and</td>
</tr>
<tr>
<td>TNF-α after a 16 week diet + exercise</td>
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<tr>
<td>weight loss intervention (Pakiz, 2017)</td>
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<tr>
<td>Study of 28 women w/ triple-negative</td>
</tr>
<tr>
<td>disease (n=13 completers provided diet-exercise). No significant change in inflammatory cytokines (CRP, IL-6, TNFα) (Swisher, 2019).</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Metabolic Syndrome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metabolic Syndrome Diagnosis by NCEP ATPIII Criteria (w/ glucose &gt;100mg/dl)</td>
</tr>
<tr>
<td>no</td>
</tr>
<tr>
<td>52%</td>
</tr>
<tr>
<td>0%</td>
</tr>
<tr>
<td>20%</td>
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<tr>
<td>40%</td>
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<tr>
<td>60%</td>
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<tr>
<td>80%</td>
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<tr>
<td>100%</td>
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</tbody>
</table>

Changes in Inflammatory/Metabolic Indices
Healthy Weight Management Study

- 85 breast cancer survivors; 15 kg > IBW
- Healthy eating, exercise and behavioral modification/CBT
- 16 weekly group sessions, 8 monthly follow-up sessions
- Mean weight loss at 12 months: 5.7 kg (vs 0.2 kg in control)
- At 16 weeks significant reductions in:
  - TNFα in both groups
  - IL-6 in intervention (p=0.06)
  - No change in VEGF or IL-8

On-going Trials in Cancer Survivors

- A large body of evidence supports the therapeutic benefit/anti-inflammatory effects of modest weight loss in overweight individuals with or without cancer
- Few published with inflammation as primary endpoint; none to specifically modify CRP/albumin ratio
- Pending trials:
  - Low Carbohydrate vs Low Fat (CHOICE) study in breast cancer (Sedlacek, USA)
  - Muscle mass, Omega-3, Diet, Exercise and Lifestyle (MODEL) study in breast cancer survivors (McDonald, Australia)
  - Lifestyle Intervention for ovarian cancer Enhanced Survival (LIVES) study (Thomson and Alberts, USA)
  - Breast cancer Weight, Energy and Lifestyle (BWEL) study: > 3000 early stage obese survivors randomized to modified DPPT / Look AHEAD weight loss program (Ligibel, USA and Canada)

EVIDENCE
Non-weight Loss Diet Interventions to Modulate Inflammation in Cancer
**Dietary Choices & Gut Inflammation**

Myles IA, Nutrition Journal, 2014

**Lignans and Inflammation**

Associated with Inflammation:

- NHANES sample
- Flax seed - major dietary source
  - Enterodiol
  - Enterolactone
- Every 1% increase in urinary lignans was associated with a 8.1% decrease in CRP and 1.9% decrease in WBC count
- Lignans have also been associated with lower cancer risk

Eichholzer M, Ca Causes Control, 2014

**Tetrahydrocurcumin**

Curcumin (THC)

- Increased bioavailability over curcumin
- Self-microemulsifying drug delivery system (research compounds)
- Regulation of oxidative stress
- Anti-inflammatory
- Neuroprotective

Olive Oil

Virgin / Extra Virgin

Review of Evidence

- Polyphenols
- Inhibition of:
  - COX-2
  - iNOS
  - Macrophage inflammatory protein (MIP-1)
  - PGE2 synthase
  - IL-6 mRNA expression
  - Nrf2 – BARD- synthetic oleanane triterpenoid

Cardenas A, Sanchez-Hidalgo M, Alarcon-de-la-Lustre C. Curr Medicinal Chem, 2013

Nrf2: Master Switch

- Resveratrol
- Curcumin
- Sulfurophane
- Allicin
- Lycopene
- Cinnamaldehyde
- Vitamin E
- Coffee
- Cocoa

Cardoso et al, Biochimie, 2013;
Martin, Goya and Ramos, Food and Chem Tox, 2013

Increased Fruit and Vegetable Intake

- SAA, IL-6 and/or CRP are biomarkers of poor prognosis in cancer
- Use of biosamples from two fruit and vegetable intervention trials, one in patients with hypertension (n=112) and one in aging patients (n=82)
- Intervention of 6 svg/8weeks and 5 svg/16 weeks, respectively
- hsCRP, IL-6 were not changed
- SAA was inversely associated with increase in fruit and vegetable intake

NHANES0 Eating Frequency and Breast Cancer Risk

- NHANES 2009-10; 2650 adult women;
- Exposure: single 24-hour recall; eating timing and frequency
- Outcome: hsCRP
- Evening calories < 30% total combined with prolonged overnight fast was assoc. with an 8% lower breast cancer risk
- Each 10% increase in evening calories consumed associated with a 3% higher CRP
- Eating 1 additional meal/day assoc. with 8% lower CRP

Marinac CR et al., PLOS One, 2015

PRACTICE APPLICATIONS

What Are The Options For Medical Nutrition Therapy?

- Modify diet to reduce inflammation
  - Quality diet; nutrients and bioactive compounds
  - Anti-inflammatory diet, DII, Mediterranean diet
  - Meal patterning: eating frequency, intermittent fasting
- Weight control
- Multidisciplinary efforts
  - Combination therapies: Anti-inflammatory medications and diet
  - Reduce inflammation, reduce toxicity and enhance diet quality to reduce cancer/recurrence risk
  - Other lifestyle factors
    - Sleep, stress management, physical activity
Mediterranean Anti-inflammatory Eating Pattern

**Weekly**
- Wine (in moderation)
- Sweets (≤2 weekly)
- Potatoes (≤3 weekly)
- Red Meat (≤3 weekly)
- Eggs (2 weekly)
- White Meat (2 weekly)
- Legumes (≥2 weekly)
- Nuts/Seeds/Olives (1-2 weekly)
- Fish (≥2 weekly)
- Dairy (preferably low fat)
- Herbs/Spices/Garlic/Onions
- Fruits (1-2 daily)
- Vegetables (Variety of colors/texture/cooked or raw) (≥2 daily)
- Olive Oil
- Bread/Pasta/Rice/Couscous/Other Cereal (preferably whole grain) (1-2 daily)
- Water and Herbal Infusions (2L daily)

**Every Day**
- Whole Grains
- Beans
- Olive Oil
- Water and Herbal Infusions (2L daily)
- Regular Physical Activity
- Adequate Rest
- Conviviality
- Biodiversity and Seasonality

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Plant-based Diets to Modulate DII

- **RCT**: vegan (n = 12), vegetarian (n = 13), pescevegetarian (n = 13), semivegetarian (n = 13), or omnivorous (n = 12).
- 24 hour recall at 2,6 months
- All non-omnivore diets were associated with a significant reduction in DII score by 2 months
- Whether this translates to lower inflammatory status is yet to be determine

Reduce Advanced Glycation End-products

- Evidence limited and remains controversial
- Reducing AGE in diet is possible
- Plant-based vs meat avoidance
  - Lower fat, saturated fat
  - Fresh foods
- Instruction to reduce high-temperature and dry cooking methods
  - Less frying, roasting, baking, grilling
  - “Charred” food products

Weight Management

- Avoid even small, incremental increases in weight
- Alert to visceral adiposity
- Diet (energy restricted) + physical activity (cardio, weight-bearing and resistance)
- Self-monitoring
  - Diet
  - Weight
  - Activity
  - Body fat/waist circumference

Meal Timing and Fasting

- Feeding associated with post-prandial inflammatory response
  - Meal frequency may reduce CRP, but reducing evening energy consumption is also necessary
  - May be attenuated by addition of anti-inflammatory foods to meal
- Ramadan fasting (n=50)
  - Fasting associated with significant reductions in IL-1β, IL-6 and TNFα
  - Rebound on re-feeding

Where Are We Now?

- Large body of evidence that inflammation contributes to cancer risk
- Compelling evidence that select inflammatory biomarkers have prognostic value for cancer
- Basic science and epidemiological evidence suggest that diet/dietary components can modify the inflammatory response
- Limited, but generally supportive evidence in cancer survivors that inflammatory response can be favorably modified to improve cancer outcomes
- The potential for RDN to impact health in those at risk for or treated for cancer through dietary guidance promoting anti-inflammatory dietary approaches is significant

QUESTIONS?

Thank you!

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4. Download and print your certificate.

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