Veterans & Parkinson’s

Environmental Exposures

The program will begin shortly.
A few notes before we start:

• All attendees will be muted and off camera.
• Share a comment by using the chat box.
• Submit a question by using the Q&A feature.

• More resources for Veterans:
  • www.Parkinson.org/Veterans

Environmental Exposures in Veterans with Parkinson’s
Our Mission

The Parkinson's Foundation makes life better for people with Parkinson’s disease by improving care and advancing research toward a cure. In everything we do, we build on the energy, experience and passion of our global Parkinson’s community.

We have everything you need to live better with Parkinson’s.

Our Goals

To help our global community live better with Parkinson’s, we pursue three goals:

- Improve care for everyone with Parkinson’s
- Advance research toward a cure
- Empower and educate our global community
PD Health @ Home

Weekly programming that includes:

- Mindfulness Mondays
- Wellness Wednesdays
- Fitness Fridays
- Expert Briefings
- EP Salud en Casa

www.Parkinson.org/Veterans

Veterans and Parkinson’s Disease

Over 100,000 veterans with Parkinson’s disease (PD) receive care through the U.S. Department of Veterans Affairs (VA).

Most people with Parkinson’s develop symptoms at 50 years of age or older. One million people in the U.S. live with Parkinson’s today. This number will rise as our population ages, as will the number of veterans diagnosed with the disease. While living with Parkinson’s can be challenging, an early diagnosis and beginning treatment can help people live well with Parkinson’s.
Thank you

DON and LORRAINE FREEBERG FOUNDATION

Environmental Exposures in Veterans with Parkinson’s
Caroline M. Tanner, MD, PhD, FAAN

- Professor of Neurology
- Vice Chair for Clinical Research
- Dept of Neurology at the Weill Institute of Neurosciences
- University of California
- San Francisco, CA

Patrick W. Welch, PhD

- Retired U.S. Marine Corps
- Infantry Squad Leader in Vietnam
- Founder of The Center for Veterans and Veteran Family Services at Daemen College
- Parkinson’s Foundation Ambassador
What Causes Parkinson's Disease?
Twins: Mother Nature's Controlled Study

- MZ twins share ~100% of genes
- DZ twins share ~50% of genes

**Hypothesis:** If Parkinson’s disease is primarily a genetic disorder, then concordance in MZ twins should be > than in DZ twins.

**Results:**
Twins aged 72-82:
MZ & DZ concordance similar;
Except in young onset MZ > DZ

Twenty year followup:
11 living, 97% valid NDI matches

Concordance for Parkinson’s Disease in Twins: a 20-year Update

- U.S. National Death Index (NDI) through 12/31/2015
- ICD codes – underlying & all causes of death

Looking across the lifespan:
Identical twins (MZ, monozygotic): 20% PD in both twins

Fraternal twins (DZ, dizygotic): 14% PD in both twins

**Conclusion:** Environment is an important contributor to the cause of PD
What Causes Parkinson's Disease?

**Genes**
- Mendelian < 20 - 30 % PD
  - Penetration reduced: Other genes & environmental factors

**GWAS:** Many variants ➔ small contributions to risk

<table>
<thead>
<tr>
<th>Risk</th>
<th>Genes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mendelian</td>
<td>- 20 - 30 % PD</td>
</tr>
<tr>
<td>Penetration reduced</td>
<td>- Other genes &amp; environmental factors</td>
</tr>
</tbody>
</table>

**Autosomal Dominant. ~ 5% PD**
- PARK-SNCA, PARK-LRRK2, PARK-VPS35

**Autosomal Recessive < 5% PD**
- PARK-Parkin, PARK-PINK1, PARK-DJ1, PARK-DNAJC6

**Complex phenotypes < 1% PD**
- Glucocerebrosidase 5 – 8 % PD

Poewe et al, 2017; Obeso et al, 2017; Nalls et al, 2019

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**PD GENERation: Mapping the Future of Parkinson's Disease**

**Why Participate**
- Improve management of your disease in the future
- Learn about your family's risk for Parkinson's
- Help scientists understand Parkinson's disease
- Assist in Parkinson's care and research
- Assist in development of improved treatments and personalized medicine for you and future generations

8,506 Participants
12.7% genetic tests completed, as of June 2023 of PD GENERation participants have a genetic link to PD, as of June 2023.

Call Our Helpline: 1-800-UPD-INFO (873-4436)

Parkinson.org
What Causes Parkinson's Disease?

Genes
- Mendelian < 20 - 30 % PD
- Penetrance reduced:
  - Other genes & environmental factors
GWAS: Many variants → small contributions to risk
- Autosomal Dominant. ~ 5% PD
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- Glucocerebrosidase 5 – 8 % PD

Environment
- Pesticides
  - Paraquat, rotenone, 2,4-D, organochlorines, organophosphates
- Solvents
  - PERC, TCE, CCl₄
- Head Injury (Traumatic Brain Injury/TBI)
- Air Pollution
- Others

Risk

Poewe et al, 2017; Obeso et al, 2015; Nalls et al, 2019

Pesticides
Pesticides & PD

Van der Mark et al, EHP, 2012

<table>
<thead>
<tr>
<th>Exposure</th>
<th>RR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Occupational or nonoccupational</td>
<td>3.63 (1.60, 8.10)</td>
</tr>
<tr>
<td>Non et al. 1993</td>
<td>1.23 (0.46, 3.30)</td>
</tr>
<tr>
<td>Zayed et al. 1996</td>
<td>2.00 (1.50, 2.60)</td>
</tr>
<tr>
<td>Siddique et al. 1996</td>
<td>1.34 (0.85, 2.13)</td>
</tr>
<tr>
<td>Wink et al. 1991</td>
<td>3.42 (2.27, 5.32)</td>
</tr>
<tr>
<td>Jimenez-Jimenez et al. 1992</td>
<td>1.33 (0.98, 1.80)</td>
</tr>
<tr>
<td>Huppert et al. 1993</td>
<td>2.00 (1.28, 3.10)</td>
</tr>
<tr>
<td>Noni et al. 1994</td>
<td>2.49 (0.53, 13.14)</td>
</tr>
<tr>
<td>Lora et al. 1997</td>
<td>1.11 (0.89, 1.38)</td>
</tr>
<tr>
<td>Die Patisse et al. 1998</td>
<td>1.61 (1.13, 2.29)</td>
</tr>
<tr>
<td>Wernert and Alaveserpa 1999</td>
<td>1.90 (1.12, 3.21)</td>
</tr>
<tr>
<td>Prez et al. 2000</td>
<td>1.34 (0.88, 2.03)</td>
</tr>
<tr>
<td>Bertram et al. 2001</td>
<td>6.01 (3.75, 9.49)</td>
</tr>
<tr>
<td>Crimmins et al. 2003</td>
<td>1.88 (1.02, 3.40)</td>
</tr>
<tr>
<td>Paternot et al. 2002</td>
<td>2.09 (0.84, 5.04)</td>
</tr>
<tr>
<td>Dunstan et al. 2003</td>
<td>2.99 (0.37, 26.00)</td>
</tr>
<tr>
<td>Vail et al. 2004</td>
<td>0.94 (0.63, 1.40)</td>
</tr>
<tr>
<td>Ascherio et al. 2006</td>
<td>1.80 (0.70, 4.50)</td>
</tr>
<tr>
<td>Frigerio et al. 2006</td>
<td>1.53 (0.85, 2.76)</td>
</tr>
<tr>
<td>Dick et al. 2007</td>
<td>1.25 (0.87, 1.81)</td>
</tr>
<tr>
<td>Kamel et al. 2007</td>
<td>1.30 (0.89, 1.93)</td>
</tr>
<tr>
<td>Hancock et al. 2008</td>
<td>1.03 (0.63, 1.69)</td>
</tr>
<tr>
<td>Birnbaum et al. 2008</td>
<td>1.71 (0.69, 4.30)</td>
</tr>
<tr>
<td>Vlahov et al. 2010</td>
<td>2.44 (0.61, 10.00)</td>
</tr>
<tr>
<td>Subtotal (I^2 = 52.4%, p = 0.005)</td>
<td>1.03 (1.38, 5.00)</td>
</tr>
</tbody>
</table>

- Pesticide use associated with PD in >50 studies worldwide
- BUT: Specific compounds rarely studied

PD in the Agricultural Health Study

Tanner, Kamel et al, EHP, 2011

<table>
<thead>
<tr>
<th>Pesticide</th>
<th>Functional Class</th>
<th>PD Risk (OR)</th>
<th>95% CI</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rotenone</td>
<td>Insecticide, piscicide</td>
<td>2.8</td>
<td>1.4-5.8</td>
<td>0.005</td>
</tr>
<tr>
<td>Paraquat</td>
<td>Herbicide</td>
<td>2.5</td>
<td>1.3-4.7</td>
<td>0.004</td>
</tr>
</tbody>
</table>

Biological plausibility:

BOTH pesticides produce a selective animal model of parkinsonism
SEARCH Study: Case Control Study of Occupational Risk Factors
Tanner et al, Arch Neurol, 2009

- 519 PD cases, 511 controls in 8 MD centers
- Lifelong, job-task-based occupational histories; other risk factors

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<th>PD Risk (OR)</th>
<th>95%CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paraquat</td>
<td>Herbicide</td>
<td>2.8</td>
<td>0.8-9.7</td>
</tr>
<tr>
<td>2,4-D</td>
<td>Herbicide</td>
<td>2.6</td>
<td>1.03-6.5</td>
</tr>
</tbody>
</table>

Agent Orange

Operation Ranch Hand: 1962-1971
Other military service
• 2009: Agent Orange Linked to Parkinson’s Disease established service-connection:

• Certain Vietnam Veterans may be eligible for: disability compensation and health care benefits.

Other Pesticide Exposures in Service Members
Examples:
Pesticides used in the Gulf War to prevent leshmania, malaria, etc.:

• Uniform impregnation:
  Carbamates, organochlorines (e.g., Lindane)
  Pyrethroids (permethrin)

• Personal repellents
  DEET

• Tents, camps
  Organophosphate pesticides (malathion, chlorpyrifos)
Chlorinated Solvents

Study 1: Gash et al, 2008
- Small Kentucky industrial plant with 30 employees
- PD in 3 co-workers
- Mild parkinsonian signs/symptoms in 14 others
- All exposed to open vapor-degreasing vat containing trichloroethylene (TCE)

<table>
<thead>
<tr>
<th>Compound</th>
<th>Odds ratio</th>
<th>95% C.I.</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>TCE</td>
<td>6.1</td>
<td>1.2-33</td>
<td>0.034</td>
</tr>
<tr>
<td>PCE</td>
<td>10.5</td>
<td>0.97-113</td>
<td>0.053</td>
</tr>
</tbody>
</table>

Study 2: Goldman et al, 2011
- 99 male twin pairs discordant for PD
- PD diagnosis validated by experts
- Lifelong job-task-specific occupational history
- Exposure assigned by industrial hygienist unaware of case status
Oral TCE causes selective dose-related degeneration of dopaminergic neurons in rat substantia nigra

Liu, et al, J Neurochem 2010

*1-trichloromethyl-1,2,3,4-tetrahydro-β-carboline

Camp Lejeune Water Supplies
History
1953-1985 - Water contaminated with TCE & PCE (i.e., PERC)
1980 - Contaminants discovered; 1987 - Wells closed

500,000 – 1,000,000 military & civilians exposed

Exposure levels:
Est. monthly median (max. mean) ug/L: PCE: 85 (158); TCE: 366 (783)
→ TCE in water more than 70 times greater than US EPA maximum contaminant level: 5 ug/l

Goldman et al, 2023

PD in Marine Base Camp Lejeune: Parkinson's Disease in ATSDR Exposure Cohort

- ATSDR cohort (n=400,000): Marines at Camp Lejeune 1975-1985 vs. Camp Pendleton
- Residential TCE and PCE exposures estimated for all Lejeune Marines (peak, cumulative)
- Linkage with:
  - VA CDW
  - CMS (Medicare)
  - NDI (cause of death)
- Manual chart review of 2,000 with a PD code
Parkinson's Disease & Camp Lejeune, N.C.

Veterans Administration and Medicare databases
Followup through 2021

**Results:**
- PD 70% more common in Lejeune vs Pendleton

**Population:**
- Lejeune 84,824 Pendleton 73,298
- 95% men
- Mean Age: Lejeune 59.6 Pendleton 59.8
- PD cases: Lejeune 279 Pendleton 171
- Crude PD prevalence: 0.33% Lejeune 0.21% Pendleton.
- Mean age at PD onset:
  - 54.7 Lejeune, 53.2 Pendleton
- OR for PD in Lejeune:
  - 1.70, 95%CI 1.39-2.07, p<0.0001

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**Dept. of Veterans Affairs 2017**
- 30 or more days of service
- 8/1/1953 to 12/31/1987
- Entitled to benefits

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**ExPERT Panel 2009—ATSDR's Water Modeling Activities at USMC Base Camp Lejeune, NC**

1.0 Introduction

**Figure 1.** Location of U.S. Marine Corps Base, Camp Lejeune, North Carolina [modified from Maslia et al. 2007].

**Historical water-supply areas of Camp Lejeune Military Reservation**

- Less than 6% of cohort had died
- Excess mortality in Lejeune only servicemembers

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**Goldman et al., 2023**
**Trichloroethylene (TCE) – Why Does It Matter?**

- Used as a solvent in multiple industries since 1920's
- Millions of pounds used annually in US
- Multiple past uses including anesthesia, coffee decaffeination, dry cleaning
- Environmentally persistent
- Present in ~33% of US water supplies
- Not monitored
- Volatile organic compound – subsurface "plumes" evaporate & concentrate in homes, offices

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**Dry Cleaning Chemicals and Parkinson’s Disease**

Vapor Intrusion of TCE in a building adjacent to a dry cleaner

Evaluated:
- 79/82 attorneys in a law office in the building
- 75 comparison attorneys not working in this building

→ PD, MSA or TCE-associated cancers were found in 25% of attorneys working near to a contaminated site but 7% of comparison attorney group
Summary: TCE & Parkinson's Disease

- Occupational & residential exposure to TCE is associated with an increased risk of Parkinson's disease
- Residential exposure to TCE is also associated with an increased risk of prodromal PD
- People with PD and prior residential exposure to TCE experience more rapid progression to disease milestones with poor prognosis - falls, fractures & psychosis
Traumatic Brain Injury

Head Injury and PD Risk in WWII Veteran Twins

Goldman, Tanner et al, Annals of Neurology 2006

Subjects: 93 discordant pairs with complete information → 26 pairs with at least one head injury
Results: 14.7% with head injury; 7.8% hospitalized
Head injury 37.4 yrs (mean) before PD onset

<table>
<thead>
<tr>
<th></th>
<th>OR</th>
<th>95% CI</th>
<th>p-value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall</td>
<td>3.0</td>
<td>1.14-9.2</td>
<td>0.023</td>
</tr>
<tr>
<td>MZ</td>
<td>3.3</td>
<td>0.86-19</td>
<td>0.092</td>
</tr>
<tr>
<td>DZ</td>
<td>2.7</td>
<td>0.64-16</td>
<td>0.23</td>
</tr>
</tbody>
</table>

→ PD risk further increased with > 1 head injury:
1 injury: OR 2.6 (1.07,6.5; p = 0.035)
2 injuries: OR 5.1 (0.54, 48; p = 0.16)
Test for trend 0.042
**BOTH Head Injury & α-Synuclein Rep 1 Gene Variant**

<table>
<thead>
<tr>
<th>Risk Factor</th>
<th>Risk from gene</th>
<th>Risk from head injury</th>
<th>Risk if BOTH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parkinson’s Disease: A Complex Disorder</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Environment pulls the trigger
December, 2013: 38 CFR 3.310(d) was amended to establish an association between TBI and certain illnesses:

In the absence of clear evidence to the contrary, Parkinsonism, including Parkinson’s disease, following moderate or severe TBI is held to be a secondary result of TBI.
Is the geographical variation in PD incidence due to differences in environment?

Incidence adjusted to 2010 US census

Fig. 2 Geographical variation in 2012 PD Incidence among 6,866,623 Medicare beneficiaries.
Military Burn Pits & Particulate Matter Exposure

- ~ 3.5 million US military exposed to burn pits, sand storms during combat deployments in last 30 years
- Burn pits contain many types of waste, organic and chemical
- Particulate matter & volatile aromatic compounds result
- PACT Act of 2022 provides health benefits for some illnesses, not including Parkinson's disease
- VA has established burn pit registry

Research In Progress
The Millennium Cohort: DoD, NHRC

- Panel 1: Enrolled 77,047 Participants
- Panel 2: Enrolled 31,119 Participants
- Panel 3: Enrolled 43,440 Participants
- Panel 4: Enrolled 50,092 Participants

Questionnaires every 3-5 years:
- Exposures
- Experiences
- Lifestyle
- Health

201,619 enrolled
- Highly diverse
- All service branches
- 30% female
- 30% non-White

MilCo Exposure Examples

Particulates, combustion products:

<table>
<thead>
<tr>
<th>Substance/threat</th>
<th>Likely exposed group</th>
<th>Exposure route</th>
<th>Exposure duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Burn pits</td>
<td>Deployed lower ranks</td>
<td>Respiratory</td>
<td>Daily in deployment</td>
</tr>
<tr>
<td>Oil well smoke</td>
<td>Vicinity burning oil fields</td>
<td>Respiratory</td>
<td>Months</td>
</tr>
<tr>
<td>Petroleum products</td>
<td>Fuel handlers, mechanics</td>
<td>Respiratory, Dermal</td>
<td>8h workday</td>
</tr>
</tbody>
</table>

Solvents, fuels:

<table>
<thead>
<tr>
<th>Substance/threat</th>
<th>Likely exposed grp</th>
<th>Exposure route</th>
<th>Exposure duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solvents/TCE</td>
<td>Armorers</td>
<td>Respiratory, Dermal</td>
<td>8h workday</td>
</tr>
<tr>
<td>Jet fuel dust suppression</td>
<td>All deployed forces in tents</td>
<td>Respiratory</td>
<td>Daily in deployment</td>
</tr>
</tbody>
</table>
### MilCo Exposure Examples: Pesticides

<table>
<thead>
<tr>
<th>Substance/threat</th>
<th>Likely exposed grp</th>
<th>Exposure route</th>
<th>Exposure duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Permethrin</td>
<td>All troops &gt;2005</td>
<td>dermal</td>
<td>chronic</td>
</tr>
<tr>
<td>Chlorpyrifos, malathion</td>
<td>All deployed forces in tents</td>
<td>respiratory</td>
<td>daily in deployment</td>
</tr>
</tbody>
</table>

- Unique exposure routes and combinations
- Chronic/repetitive dosing

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### MilCo Exposure Examples: Unique, biologically plausible exposures

<table>
<thead>
<tr>
<th>Substance/threat</th>
<th>Likely exposed grp</th>
<th>Exposure route</th>
<th>Exposure duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pyridostigmine bromide</td>
<td>All deployed forces</td>
<td>oral ingestion</td>
<td>daily in deployment</td>
</tr>
<tr>
<td>Low level sarin</td>
<td>Vicinity of Khamisiyah</td>
<td>respiratory</td>
<td>&lt;1 day twice</td>
</tr>
<tr>
<td>Depleted uranium embedded fragments</td>
<td>friendly fire injuries</td>
<td>subdermal</td>
<td>chronic</td>
</tr>
<tr>
<td>Combat stress</td>
<td>All deployed forces</td>
<td>Combat stress</td>
<td>All deployed forces</td>
</tr>
</tbody>
</table>
Parkinson’s Disease – Presumptive Relationship to Qualifying Military Service

Presumptive diseases: Certain diseases assumed by VA to be related to a Veteran’s qualifying military service.

Parkinson’s disease:
Agent Orange (qualifying service in Vietnam, Korea, other) + Parkinsonism 2021
Camp Lejeune residence 1953-1987 (Cl solvents in H₂O)
Traumatic brain injury (2ary)
Hope for the Future

What Causes Parkinson's Disease?

Genes
- Mendelian < 20 - 30 % PD
- Penetration reduced: Other genes & environmental factors
- GWAS: Many variants → small contributions to risk
- Autosomal Dominant. ~ 5% PD
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Environment
- Pesticides
  - Paraquat, rotenone, organochlorines, organophosphates
- Solvents
  - PERC, TCE, CCl₄
- Head Injury
- Air Pollution
- Others

Physical Activity
- Coffee & Tea Intake
- Tobacco Use
- Other

Risk

Poewe et al, 2017; Obeso et al, 2017; Nalls et al, 2019
**Precision Medicine**

- Personalized treatment – right person, right time
- Incorporates genetic, environmental, lifestyle characteristics

Requirements:
- Risk stratification
- Early detection of pathophysiologic processes
- Intervention that targets specific molecular pathophysiology in an individual

---

**Biological vs Clinical Diagnosis of Parkinson's Disease**

1stary

Genetic Risks
Exposure Risks
Behavioral Risks

PD Diagnosis as defined by biology
PD Diagnosis based on current clinical diagnostic criteria

Time

Chahine et al, 2023
**Path to Parkinson Disease Prevention**

**Conclusion and Outlook**

Next Steps

P2P Clinical Trial:
- In planning stages
- PPMI Participants, Not PD
- Biologically-defined Risk
- Interventions to delay onset of motor or cognitive PD

Tanya Simuni, Christopher Coffey, Andrew Siderowf, Caroline Tanner, Sohini Chowdhury, Catherine Kopil, Todd Sherer, Michael Brumm, Karl Kieburtz, Kimberly Fabrizio, Ben Saville, Cora Allen-Savietta, Barbara Wendelberger, Amy Crawford and Ken Marek on behalf of the PPMI Investigators.

**Hope for the Future - Agents in Active PD Drug Trials**

63 Disease Modifying Therapy (DMT) Trials:
- 25 Phase I
- 32 Phase II
- 6 Phase III

DMT Therapy categories:
- Antiinflammatory
- Antioxidants
- Cell therapy
- DMT Other
- Energy and mitochondria
- GBA
- GLP-1 agonists
- Kinase
- LRRK2
- Microbiome/GIT
- Neurotrophic factors
- Targeting alpha synuclein
THANK YOU!!
Volunteers & Research Partners:
Patients, Controls, Family & Friends

Sponsors:

THANK YOU to Colleagues!

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Cameron Dietiker
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Marta San Luciano
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Cheryl Meng
Farah Kausar
Monica Korell
Steven Cummings

PHREI
G. Webster Ross
Helen Petrovitch
Lon White
AK Native Medical Center
Brian Trimble
Shiga University
Robert Abbott
Kuakini Hospital
Kamal Masaki

NIH Aging
NIEHS
Freya Kamel
David Umbach
Stanford University
Lorene Nelson
James Tetrud
J W Langston
Kaiser Permanente DOR
Stephen Van Den Eeden
Kathleen Albers
NCI
Aaron Blair
NIA
Andrew Singleton
Columbia University
Ruth Ottman
Richard Mayeur
Karen Marder
Northwestern University
Tanya Simuni
Toronto Western Hospital
Connie Marras
Massachusetts General/Harvard
Michael Schwarzschild

Capital U, Beijing
Bill Piu Chan
Favaloro U, Buenos Aires
Anabel Chade
Buddhist Tzu Chi Hsp, Taiwan
Raymond Lo
Univ of Lübeck
Meike Kasten
University of Michigan
Kelvin Chou
Cleveland Clinic
Hubert Fernandez
University of Pittsburgh
Lana Chahine
Franca Cambi
Rush University
Cindy Comella
Christopher Goetz
University of Wisconsin
Kathleen Shannon
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Jonas Ellenberg
Andrew Siderowf
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David Oakes
IND
Kenneth Marek