

ANNALS OF THE AMERICAN THORACIC SOCIETY®

A journal dedicated to advancing care in respiratory
diseases, sleep disorders, and critical illness

EDITOR

DAVID LEDERER, M.D.
New York, NY

SENIOR DEPUTY EDITOR

ROBERT KOTLOFF, M.D.
Cleveland, OH

EDITOR, ANNALSATS SUPPLEMENTS

ADAM WANNER, M.D.
Miami, FL

ASSOCIATE EDITOR, ANNALSATS SUPPLEMENTS

KRISTEN L. VERALDI, M.D., PH.D.
Pittsburgh, PA

PODCAST EDITOR

GREGORY TINO, M.D.
Philadelphia, PA

VIDEO EDITOR

SILPA KREFFT, M.D., M.P.H.
Denver, CO

DEPUTY EDITORS

DAVID H. AU, M.S., M.D.
Seattle, WA

COLIN R. COOKE, M.D., M.SC., M.S.
Ann Arbor, MI

SHARON DELL, M.D.
Toronto, Ontario, Canada

MICHAEL K. GOULD, M.D., M.S.
Pasadena, CA

SUSAN REDLINE, M.D.
Boston, MA

ASSOCIATE EDITORS

SURYA P. BHATT, M.D.
Birmingham, AL

SAMUEL M. BROWN, M.D., M.S.
Murray, UT

KECIA CARROLL, M.D.
Nashville, TN

KRISTINA CROTHERS, M.D.
Seattle, WA

DAVID FELLER-KOPMAN, M.D.
Baltimore, MD

HENRY E. FESSLER, M.D.
Baltimore, MD

HAYLEY B. GERSHENGORN, M.D.
Miami, FL

CHRISTOPHER GOSS, M.D., M.SC.
Seattle, WA

FERNANDO HOLGUIN, M.D., M.P.H.
Aurora, CO

KATHLEEN O. LINDELL, PH.D., R.N.
Pittsburgh, PA

MAX O'DONNELL, M.D., M.P.H.
Brooklyn, NY

YÜKSEL PEKER, M.D., PH.D.
Istanbul, Turkey

KRISTIN RIEKERT, PH.D.
Baltimore, MD

GREGORY SAWICKI, M.P.H., M.D.
Boston, MA

HIRAN SELVADURAI, M.D., F.R.A.C.P., PH.D.
Sydney, Australia

KATIE L. STONE, PH.D., M.A.
San Francisco, CA

COREY VENTETUOLO, M.D., M.S.C.R.
Providence, RI

ALLAN J. WALKEY, M.D., M.SC.
Boston, MA

GEORGE R. WASHKO JR., M.D., M.M.SC.
Boston, MA

JUAN WISNIVESKY, DR.P.H., M.D.
Scarsdale, NY

SECTION EDITORS

Public Health and Policy

MARY RICE, M.D., M.P.H.
Boston, MA

JONATHAN SAMET, M.D.
Los Angeles, CA

NEIL W. SCHLUGER, M.D.
New York, NY

DONA UPSON, M.D., M.A.
Albuquerque, NM

The Clinical Physiologist
JOHN KREIT, M.D.
Pittsburgh, PA

ERIK SWENSON, M.D.
Seattle, WA

Sleep Fragments
BERNIE SUNWO, M.D.
San Francisco, CA

MIHAELA TEODORESCU, M.D.
Madison, WI

The Expert Clinician
PETER CLARDY, M.D.
Boston, MA

CHARLIE B. STRANGE III, M.D.
Charleston, SC

The Proceduralist
GEORGE EAPEN, M.D.
Houston, TX

SEPTIMIU MURGU, M.D.
Chicago, IL

Thoracic Radiology
JULIANA BUENO, M.D.
Chicago, IL

JONATHAN CHUNG, M.D.
Chicago, IL

STEPHEN HOBBS, M.D.
Lexington, KY

Ultrasound Reflections
GREGORY A. SCHMIDT, M.D.
Iowa City, IA

On the Receiving End
KATHLEEN O. LINDELL, PH.D., R.N.
Pittsburgh, PA

Innovations and Provocations
THEODORE J. IWASHYNA, M.D., PH.D.
Ann Arbor, MI

EDITOR EMERITUS
JOHN HANSEN-FLASCHEN, M.D.
Philadelphia, PA

ATS DOCUMENTS EDITOR
KEVIN C. WILSON, M.D.
Boston, MA

ATS DOCUMENTS ASSISTANT EDITOR
RENDIA SOYLEMEZ WIENER, M.D., M.P.H.
Boston, MA

EDITORIAL PRODUCTION AND PEER REVIEW OFFICES

ATS Editorial Office
25 Broadway, 18th Floor
New York, NY 10004

Tel: 212-315-8623
FAX: 212-315-8613

Internet: <http://www.thoracic.org>

CHIEF, JOURNALS
DIANE GERN

Peer Review Manager
MARC BENDIAN

Senior Manager, Technical Peer Review
FAY LING

Director, Editorial/Production
ERIC GUMPERT

Production Editor
KATHERINE YOUNG

Cover Art Design
DORCAS GELABERT

Digital Media Specialist
SEAN STEVENS

Business and Finance
NEIL KERLEY

Subscriptions
MURICIA ALEXANDER

Advertising Representative
Cunningham Associates

180 Old Tappan Road
Old Tappan, NJ 07675

Tel: 201-767-4170
FAX: 201-767-8065

EDITORIAL BOARD

TIMOTHY R. AKSAMIT, M.D.
Rochester, MN

NADINE AL-NAMAANI, M.D., M.S.
Philadelphia, PA

SELIM M. ARCASOY, M.D.
New York, NY

MICHELE C. BALAS, M.D.
Columbus, OH

MATTHEW BALDWIN, M.D., M.S.
New York, NY

BRUCE G. BENDER, PH.D.
Denver, CO

CRISTINE E. BERRY, M.D., M.H.S.
Tucson, AZ

MICHEL BOIVIN, M.D.
Albuquerque, NM

CHRIS CARLSTEN, M.D., M.P.H.
Vancouver, BC, Canada

JOHN CARROLL, M.D.
Little Rock, AR

WILLIAM CHECKLEY, M.D.
Baltimore, MD

IRA CHEIFETZ, M.D., F.C.C.M., F.A.A.R.C.
Durham, NC

SUSMITA CHOWDHURY, M.D.
Detroit, MI

ANDREW M. CHURG, M.D., PH.D.
Vancouver, BC, Canada

ROBYN T. COHEN, M.D.
Boston, MA

JOAO DE ANDRADE, M.D.
Birmingham, AL

JOSHUA DIAMOND, M.D.
Philadelphia, PA

JESSICA DINE, M.D.
Philadelphia, PA

M. BRADLEY DRUMMOND, M.H.S., M.D.
Chapel Hill, NC

MICHAEL EBERLEIN, M.D.
Iowa City, IA

EVANS R. FERNANDEZ PEREZ, M.D., M.S.
Denver, CO

ANNE FITZPATRICK, PH.D., R.N.
Atlanta, GA

PATRICK A. FLUME, M.D.
Charleston, SC

KWUN FONG, M.B.B.S., F.R.A.C.P., PH.D.
Brisbane, Australia

JOSEPH K. GERALD, M.D., PH.D.
Tucson, AZ

MICHELLE GONG, M.S., M.D.
Bronx, NY

NISHANT GUPTA, M.D.
Cincinnati, OH

DENIS HADJILIADIS, M.D., M.H.S.
Philadelphia, PA

AARON HAMVAS, M.D.
Chicago, IL

JOHN HANSEN-FLASCHEN, M.D.
Philadelphia, PA

ROSS HILL, M.D.
New York, NY

CATHERINE HOUGH, M.D., M.S.C.
Seattle, WA

MICHAEL HOWELL, M.D., M.P.H.
Chicago, IL

ROBERT HYZY, M.D.
Ann Arbor, MI

DANIEL JACKSON, M.D.
Madison, WI

NIZAR JARJOUR, M.D.
Madison, WI

KERRI JOHANNSON, M.D., M.P.H.
Calgary, Alberta, Canada

RAVI KALHAN, M.D., M.S.
Chicago, IL

JAMES R. KLINGER, M.D.
Providence, RI

FRANCINE LADEN, Sc.D.
Boston, MA

FRANK T. LEONE, M.D., M.S.
Philadelphia, PA

ROBERT LODDENKEMPER, M.D.
Berlin, Germany

ROBERTO MACHADO, M.D.
Chicago, IL

ULYSSES J. MAGALANG, M.D.
Columbus, OH

JESS MANDEL, M.D.
San Diego, CA

DAVID M. MANNINO, M.D.
Lexington, KY

MITCHELL L. MARGOLIS, M.D.
Philadelphia, PA

CARLOS MARTINEZ, M.D., M.P.H.
Ann Arbor, MI

STEPHEN C. MATHAI, M.D., M.H.S.
Baltimore, MD

JENNIFER McCALLISTER, M.D.
Columbus, OH

SUSANNA A. McCOLLEY, M.D.
Chicago, IL

FRANCIS X. McCORMACK, M.D.
Cincinnati, OH

ATUL MEHTA, M.D.
Cleveland, OH

NUALA J. MEYER, M.D., M.S.
Philadelphia, PA

MARK MIKKELSEN, M.D., M.S.C.E.
Philadelphia, PA

MEHDI MIRSAEIDI, M.D., M.P.H.
Miami, FL

JOSHUA MOONEY, M.D.
Stanford, CA

KEVIN MORTIMER, PH.D.
Liverpool, United Kingdom

MARILYN MOY, M.D.
West Roxbury, MA

SUSAN MURIN, M.D.
Sacramento, CA

BOULOS NASSAR, M.D.
Coralville, IA

ANA NAVAS-ACIEN, M.D., M.P.H., PH.D.
New York, NY

GIORA NETZER, M.D.
Baltimore, MD

DAVID E. OST, M.D., M.P.H.
Houston, TX

MARY PORTEOUS, M.D.
Philadelphia, PA

BHARATI PRASAD, M.D., M.S.
Chicago, IL

JOHN REILLY, M.D., M.S.C.E.
Philadelphia, PA

CAROLYN ROCHESTER, M.D.
New Haven, CT

KRISTIE ROSS, M.D.
Cleveland, OH

CHRISTOPHER RYERSON, M.D.
British Columbia, Canada

JAY H. RYU, M.D.
Rochester, MN

MARGARET SALISBURY, M.D.
Ann Arbor, MI

DEAN SCHRAUFNAGEL, M.D.
Chicago, IL

WILLIAM SCHWEICKERT, M.D.
Philadelphia, PA

SANJAY SETHI, M.D.
Buffalo, NY

VIBHU SHARMA, M.D.
Chicago, IL

HUAN-ZHONG SHI, M.D., PH.D.
Beijing, China

MARK D. SIEGEL, M.D.
New Haven, CT

JONATHAN SINGER, M.D.
San Francisco, CA

CHRISTOPHER G. SLATORE, M.D.
Portland, OR

SHEREE SMITH, PH.D.
Sydney, Australia

AKSHAY SOOD, M.D., M.P.H.
Albuquerque, NM

MICHAEL L. STANCHINA, M.D.
Providence, RI

MARY E. STREK, M.D.
Chicago, IL

DIANE STROLLO, M.D.
Pittsburgh, PA

PATRICK STROLLO, M.D.
Gibsonia, PA

RHONDA SZCZESNAK, PH.D.
Cincinnati, OH

ALLISON TURNBULL, D.V.M., M.P.H., PH.D.
Baltimore, MD

ANIL VACHANI, M.D.
Philadelphia, PA

RENDIA S. WIENER, M.D., M.P.H.
Boston, MA

DOUGLAS B. WHITE, M.D., M.A.S.
Pittsburgh, PA

RICHARD G. WUNDERINK, M.D.
Chicago, IL

IAN YANG, M.B.B.S., PH.D.
Brisbane, Australia

K. RANDALL YOUNG, JR., M.D.
Hershey, PA

Annals of the American Thoracic Society: Notice to Subscribers and Contributors

The *Annals of the American Thoracic Society*® (eISSN 2325–6621; ISSN 2329–6933) is published monthly, with supplements, by the American Thoracic Society. *AnnalsATS* is an official publication of the American Thoracic Society. The contents of *AnnalsATS* are included in MEDLINE®, Index Medicus®, PubMed®, and Chemical Abstracts®. *AnnalsATS* is now indexed in the Web of Science™ (impact factor coming June 2018). Published at 25 Broadway, 18th Floor, New York, NY 10004 by the American Thoracic Society. Periodicals postage paid at New York, NY and additional mailing offices. POSTMASTER: Send address changes to *Annals of the American Thoracic Society*, American Thoracic Society, 25 Broadway, 18th Floor, New York, NY 10004. Copyright © 2018, by the American Thoracic Society.

ATS Membership: Subscription to the *Annals of the American Thoracic Society*® (*AnnalsATS*) is one of the benefits of membership in the American Thoracic Society (ATS). Further information is available from the ATS Office, 25 Broadway, 18th Floor, New York, NY 10004, or from the ATS website: <http://www.thoracic.org>.

Subscription Rates: For subscription information contact the ATS subscriptions department, 212-315-8687 or subscriptions@thoracic.org.

Mission Statement: To improve the health of adults and children with respiratory diseases, sleep disorders, and critical illness through dissemination of research and clinician education. *AnnalsATS* is available online at <http://www.atsjournals.org>.

The American Thoracic Society publishes the *Annals of the American Thoracic Society*® in furtherance of its educational and scientific purposes as a nonprofit and tax-exempt organization. All articles published in the Publication are subject to copyrights owned by the American Thoracic Society or other individual(s) or entity(ies). Reproduction of any article by any means without the express prior authorization of the American Thoracic Society is prohibited. The statements and opinions expressed in the Publication only represent those of individual author(s) and do not reflect the policies or opinions of the American Thoracic Society. Statements and claims concerning the effectiveness, quality, or safety of the products or procedures advertised in the Publication are solely those of the advertiser and do not represent any endorsement or approval by the American Thoracic Society. The American Thoracic Society assumes no responsibility for the content of the Publication and expressly disclaims all liability for any damages arising out of use, reference to, or reliance on the contents of the Publication.

Manuscripts: Contributors are requested to read the Instructions for Authors, posted on <http://www.atsjournals.org/page/AnnalsATS/instructions> or obtained from the Peer Review Office upon request. Failure to follow these instructions may cause delay in publication. Manuscripts must be submitted online using ScholarOne at <http://atsjournals.manuscriptcentral.com>. Copyright forms are to be downloaded at the same site and emailed to forms@thoracic.org. If you have questions or encounter problems with online submission, please contact Marc Bendian, Peer Review Manager (mbendian@thoracic.org) or Fay Ling, Senior Manager, Technical Peer Review (fling@thoracic.org). Offprints may be ordered via the links that are e-mailed to corresponding authors in advance of publication.

Permission Requests: For permission requests, please contact the Publisher (dgern@thoracic.org) or permissions@thoracic.org. The ATS solely reserves the right to decline any request for any reason.

Reprints and E-prints: Requests for quotations for commercial reprints and e-prints will be provided based on the language and area of distribution. For English-language prints distributed in the U.S. and Canada, contact Amy Schriver from Sheridan Reprints at 800-635-7181 ext. 8065 or e-mail to amy.schriver@sheridan.com.

For translated and English-language prints distributed outside the U.S. and Canada, contact the Publisher (dgern@thoracic.org) who will forward your request to an agent of the ATS. The ATS solely reserves the right to decline any request for any reason.

Advertisers: Rates will be furnished by Cunningham Associates (address listed on masthead). The publisher reserves the right to decline any advertising submitted. Billing directed to the advertising agency is approved on condition that the advertiser will accept full responsibility for payment if the agency does not remit within 90 days.

Journal Copyright Notice: Copyrights in the Journal and in all articles published in the Journal are owned by the American Thoracic Society or other individuals or entities. No part of this Journal or of any article may be reproduced, stored in a retrieval system, or transmitted in any form or by any means, electronic, mechanical, photocopying, recording, or otherwise, in whole or in part, without the prior written permission of the American Thoracic Society. For permission, contact Diane Gern, Publisher, dgern@thoracic.org.