The Lifetime Surveillance of Astronaut Health

Newsletter

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Editor’s note: The LSAH Newsletter is back and with a new focus: Communicate updates to how LSAH does business as well as inform readers about new surveillance efforts. We are happy to be back and hope you enjoy!

The TREAT Astronauts Act

By Meredith Rossi, MPH, Mary Van Baalen, PhD, Lesley Lee, MS

On March 21, 2017, the National Aeronautics and Space Administration (NASA) Transition Authorization Act of 2017 was signed into law. The law includes “To Research, Evaluate, Assess, and Treat Astronauts Act,” also referred to as the “TREAT Astronauts Act”. The TREAT Astronauts Act authorizes NASA to monitor, diagnose, and treat conditions associated with spaceflight.

NASA currently provides medical monitoring services to former NASA astronauts and payload specialists through the Lifetime Surveillance of Astronaut Health (LSAH) program at Johnson Space Center (JSC). The TREAT Astronauts Act authorizes NASA i) to expand on current medical monitoring services and, ii) to begin providing diagnostic and treatment services for conditions related to spaceflight. In October, NASA sent a letter to the astronaut community summarizing the TREAT Act, specifying that former NASA astronauts and payload specialists who have flown at least one spaceflight mission may be eligible to receive these services.

This continuation and expansion of medical monitoring and diagnostic services will facilitate early detection of health conditions that may be associated with exposures incurred during spaceflight or spaceflight training. Data from this program will be used to tailor treatments for individual astronauts and will enable NASA to cultivate evidence more effectively to understand and mitigate the long-term health risks of human spaceflight, as well as support the physical and mental well-being of astronauts during future exploration missions.

NASA will be developing the implementation plan for the TREAT Act expansion over the next year. Currently, the Potomac Institute in Washington, DC is conducting an independent cost assessment that is due to Congress in March 2018. More information will be provided to the astronaut community as it becomes available and as NASA explores the most effective ways of disseminating information on this program.

Until NASA finalizes how it will implement the TREAT Act, JSC and LSAH will continue to provide the current medical monitoring exams at JSC to all former NASA astronauts and payload specialists, including those who have not flown a mission. In addition, the Workers’ Compensation Specialist at the JSC Clinic, Wanda Thompson, is available to assist with submission of claims to the Department of Labor Workers’ Compensation process for work-related conditions. Wanda can be reached by phone at (281) 483-3252.

Dr. Ronak Shah of the JSC Clinic will be presenting information about the TREAT Act during the astronaut reunion events in December 2017. NASA, the JSC Clinic, and LSAH are excited about this opportunity to provide enhanced services to all former astronauts and payload specialists, and look forward to supporting all who qualify.
Audiometric Surveillance: Benefits for Individuals and Occupational Surveillance

By Jessica Shafer, MPH, Richard Danielson, PhD

Audiometric testing is a standard part of the annual and flight physical exams for both active and retired astronauts. When tested in the clinic by Dr. Danielson, the JSC Audiologist, the results of these periodic tests yield informative trends in individual hearing profiles over time and contribute to LSAH population surveillance.

The results of individual pure-tone audiometric tests are routinely compared to the initial NASA audiogram and reviewed for any indications of increased hearing loss. In particular, these reviews look for early flags of high frequency hearing loss due to noise exposures (either occupational or off-the-job) before a permanent hearing problem occurs. Other off-nominal audiometric results can prompt a review of clinic records for other medical disorders that may lead to hearing impairment. Even after leaving the active astronaut corps, the hearing tests done as part of the annual LSAH physical can reveal indications of non-occupational noise damage or other hearing problems that should be referred for further evaluation and treatment. Dr. Danielson is happy to provide JSC patients with individual counseling about hearing loss prevention and recommendations for improving hearing.

JSC’s substantial audiometric database provides a unique tracking of an individual’s hearing status (for decades, in some cases), and it yields aggregate data from the astronaut population for analyses. In 2013, LSAH and Dr. Danielson collaborated to create an individualized report for annual exam debriefs that allows each individual to see graphic representations of hearing loss trends observed in their periodic physicals. This report provides graphical comparisons of audiometric results to data acquired from other individuals of the same gender and age from two different populations: 1) a very large “non-industrial noise-exposed population” and 2) the entire NASA astronaut corps. See Figures 1 and 2 for examples of these comparison graphs. All comparisons are made using high-frequency hearing thresholds (averaged at 2, 3, and 4 kHz), which are commonly considered to be early identifiers of noise-related hearing loss and potential hearing impairment. These two graphical displays illustrate how the individual’s hearing thresholds have progressed over time (or remained stable), and whether any intervention may be warranted. This report is provided to all current and former crewmembers as part of each audiometric exam debrief. We hope the testing and summary of each person’s information is beneficial in protecting hearing health.

Figure 1. Example of an individual’s hearing thresholds at 2, 3, and 4 kHz compared to a “non-industrial noise-exposed population” at the same age (black line), as well as the variability (green line: 90th percentile, orange line: 10th percentile).

Figure 2. Example of an individual’s hearing thresholds at 2, 3, and 4 kHz compared to the male astronaut corps.
Over the last several years of ISS operations, anecdotal reports increasingly suggested that ISS crewmembers were developing carbon dioxide (CO\textsubscript{2})-related symptoms such as headache, lethargy, malaise, listlessness, and fatigue at lower CO\textsubscript{2} levels than they do on Earth. Headache has been reported in situations where crewmembers work inside a confined space with reduced airflow and during periods when all the crewmembers were together in a single location. Crew also reported feeling better and having improved performance when CO\textsubscript{2} levels were low.

To study the effects of CO\textsubscript{2} on the ISS more rigorously, a CO\textsubscript{2} Data Team was formed as a multiyear collaboration between the Lifetime Surveillance of Astronaut Health (LSAH), the Space Toxicology Office, and the Space Medicine Operations Division at the NASA Johnson Space Center. The objectives of this working group were to study CO\textsubscript{2} levels since the beginning of the ISS Program, identify in-flight headache events, and analyze the relationship between the partial pressure of carbon dioxide (ppCO\textsubscript{2}) and headache. This work was published in the Journal of Occupational and Environmental Medicine in May 2014\textsuperscript{1}.

Methods

LSAH epidemiologists compiled the medical data and converted it to an unattributable format for team use. Data were compiled on all USOS astronauts who completed an ISS mission between March 14, 2001 and May 31, 2012. Cases of headache were based on crewmember reports of in-flight headache symptoms captured from transcripts of two sources: private medical conferences (PMCs) and Space Medicine Operations Team (SMOT) meeting minutes. PMCs are private video teleconferences between a crewmember and their crew surgeon, held daily for the first 5 days of flight and weekly thereafter, to discuss the health of the crewmember while on orbit. The SMOT meeting is a physician-only, cross-space agency teleconference held weekly to review the health status of the entire crew onboard ISS.

Due to possible confounding by Space Adaptation Syndrome (SAS), headaches reported in the first 7 days of flight were excluded from the analysis. All headaches after Flight Day 7 were included in the analysis, regardless of potential causes. A total of 46 reported headaches and 1,670 non-reports were observed.

CO\textsubscript{2} measurements from ISS instruments were obtained by the JSC Space Toxicology Office. The Major Constituent Analyzer (MCA) in the United States On-orbit Segment (USOS) was the primary source of CO\textsubscript{2} monitoring used in this study because its calibration and performance were well understood by the Environmental Control and Life Support System (ECLSS) team. From May 13, 2011 to January 28, 2012, backup sensors were used due to MCA failures. We assumed that environmental CO\textsubscript{2} measurements were representative of the individual exposures. We were not able to account for potential localized pockets of elevated

Occupational Surveillance: Relationship between Carbon Dioxide Levels and Reported Headaches on the International Space Station

By Mary Wear, PhD

Analysis of audiometric data is also useful for flight surgeons and LSAH during evaluation of health impacts due to space flight. For example, mission-associated changes (from pre-flight to post-flight) in hearing thresholds can suggest a risk of excessive noise exposures in-flight, which in turn supports continued efforts to mitigate noise exposure for future long-duration missions and vehicle design. A recent analysis showed only 3 of the 45 ISS crewmembers on Expeditions 1 through 47 experienced a significant mission-related hearing threshold shift, all of which resolved on retest shortly after landing. These data support the success of noise mitigation efforts on ISS as well as the audiometric surveillance efforts.

In summary, the audiometric monitoring element of the LSAH surveillance program offers benefits to both the crewmembers and JSC’s Human Health and Performance Directorate.

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CO₂ because those were rarely measured.

**Results**

Figure 1. International Space Station (ISS) CO₂ levels over time. Time bands indicate ISS Expeditions for which CO₂ levels were controlled by chits.

Figure 1 shows the CO₂ levels over time during the study period. Seven-day average CO₂ levels over the ISS program are shown, since it is most reflective of the medical event-reporting period. At the time of this work, the Flight Rule specified that action must be taken to lower the ppCO₂ if levels reached or exceeded 7.6 mmHg. This action was required even in the absence of CO₂-related symptoms. When CO₂ levels averaged higher than 5.3 mmHg over 5 days or 6.0 mmHg over 24 hours, flight surgeons were consulted. The presence of CO₂-related symptoms below these levels has led to flight rule waivers, known as “chits”, to decrease CO₂ levels on a mission-to-mission basis until the flight rules can be changed permanently. The time periods during which chits were in place are indicated by color bands in Figure 1. Early in the ISS program, chits controlled ppCO₂ to 5.3 mmHg or levels that were contingent on the duration and magnitude of the excursion or timing relative to complex operations. Since Expedition 23 in 2010, chits have routinely controlled CO₂ levels to 4 mmHg or less.

The estimated incidence of headache per week in a crewmember was 4.6% before Expedition 23 and decreased to 1.8% afterwards, when chits were used to keep ppCO₂ at or below 4 mmHg. CO₂ level, age at launch, time in-flight, and data source were all significantly associated with headache for 24-hour and 7-day averages and peaks. For each 1-mmHg increase in CO₂, the odds of a crewmember reporting a headache almost doubled; for each year older, a crewmember was at launch the odds of a headache decreased by almost 10%; for each day spent on the mission the odds of a headache decreased 0.6%. Our study did not find a statistically significant effect pertaining to sex of an individual in predicting headaches.

From the parameter estimates using the median value for the other covariates, a plot was generated to predict the probability of headache based on the 7-day average CO₂ (see Figure 2). For example, to keep the risk of headache below 3%, the 7-day average CO₂ must be below 4 mmHg.

Figure 2. Predicted probability of headache based on 7-day average CO₂ levels.

**Discussion**

Compared to typical terrestrial ambient indoor and outdoor ppCO₂ and CO₂ levels onboard the ISS are chronically elevated but below levels demonstrated to cause detrimental physiological effects in all but the most recent ground-based studies of effects of CO₂ on cognition. However based on the current analysis, the higher CO₂ levels present on ISS have a statistically significant association with the incidence of reported headaches in a healthy astronaut cohort. While the incidence is not high, the concern of the space medical community is that headaches may be an indicator of underlying pathophysiology.

Our results showed that a crewmember’s age at launch and length of time spent in-flight were inversely related to headache reports. A possible explanation is that older crewmembers may have less
compliant vasculature and therefore be less susceptible to CO₂-mediated vasodilation. There may also be an adaptation to chronic CO₂ exposure.

According to our analysis, 7-day average CO₂ concentrations would need to be maintained below 2.5 mmHg to keep the risk of headache below 1%, a standard threshold used in toxicology and aerospace medicine. However, a single study is not sufficient to define a new operational limit.

Post-Analysis Work

The results of this analysis have provided guidance in supporting management of CO₂ to lower levels using chits (current chit controls 24-hour average to 3 mmHg). However, this initial analysis has limited value for daily/hourly management of the ISS Environmental and Thermal Operating Systems (ETHOS) systems. As a result, the LSAH CO₂ Data Team and the ETHOS group are collaborating to combine our unique data sets and expertise to create a mathematical model that will better inform ISS operations. These additional analyses along with further research studies of visual and cognitive effects on acute and chronic exposure to CO₂ in the setting of spaceflight will allow NASA to inform flight standards and develop new hardware requirements.

In March 2016, the Human System Risk Board accepted a recommended target of 1.5 - 2.0 mmHg for exploration vehicles. In April 2016, the Technical Interchange Meeting recommended that life support teams seek to achieve levels as low as possible for Exploration vehicles. In August 2017, the JSC Toxicologist, Dr. Valerie Ryder, recommended that CO₂ should be reduced to levels as low as reasonable achievable (ALARA) in order to reduce and/or prevent crew symptoms. For ISS, this is an average 24-hr level of 3 mmHg during 6 crew operations. For Exploration, the NASA target has been set at 2 mmHg, but development of technologies that can further reduce levels are encouraged.

Several additional CO₂ research analyses were presented at the Human Research Program Investigators’ Workshop in January 2017. Ryder, et al.,² did not identify dose-dependent changes in psychological measures (as measured by Cognition battery and Strategic Management Software) following acute CO₂ exposures ranging from 0.5-3.8 mmHg. The CO₂ Data Team also examined the relationships between in-flight CO₂ and measures of the eye to understand how CO₂ may be related to Spaceflight Associated Neuro-Ocular Syndrome but results were inconclusive³. At the Aerospace Medical Association Annual Meeting in May 2017, Cole, et al.,⁴ reported that, as with headaches, there is a positive association between CO₂ levels and reports of congestion on ISS. These additional analyses along with further study of visual and cognitive effects on acute and chronic exposure to CO₂ in the setting of spaceflight will allow NASA to inform flight standards and develop new hardware requirements.

References

Exploring Cardiovascular Disease Risk among Astronauts

By: Jacqueline Charvat, PhD

In July 2017, The National Academy of Medicine reviewed NASA’s Evidence Reports on Human Health Risks including the “Risk of Cardiac Rhythm Problems during Spaceflight.” Panelists and renowned cardiologists gave their thoughts on how well this risk is currently understood and if it is of concern for long duration spaceflight.

Arrhythmias, or heart rhythm disturbances, have been observed in some astronauts during spaceflight. However, it is not known if these arrhythmias were due to spaceflight, pre-existing conditions, or the natural aging process. The clinical experts discussed NASA data and determined that the arrhythmias observed in U.S. crewmembers to date have been of minor clinical significance. Recent ISS cardiovascular research has contributed to NASA’s evidence base. The ‘Integrated Cardiovascular’ study sought to understand how the heart changed during flight and if these changes increased the susceptibility to arrhythmias both during and directly after flight¹. The current ‘CardioOx’ study aims to understand how biomarkers of oxidative and inflammatory stress change during and up to five years following spaceflight. However, only one study to date has focused on cardiovascular disease outcomes among astronauts³. The National Academy of Medicine panel of experts acknowledged that NASA needs to gain a stronger understanding of the risk for all cardiovascular diseases over the long term as astronauts age, not only in immediate association with a spaceflight mission.

To that end, LSAH is currently working with the JSC Cardiovascular and Vision Laboratory on cohort studies that compare the cardiovascular outcomes of astronauts to those of other healthy populations. Ten different external cohorts were evaluated, with two cohorts selected to compare to the astronauts: Air Force aviators and healthy adults from the Cooper Center Longitudinal Study. The Air Force cohort was chosen because this population is similar to the astronaut corps with regard to general health at selection, screening processes, and certain occupational exposures. The Cooper Center cohort was chosen because a vast array of clinical cardiovascular measures has been collected in a longitudinal manner, which is similar to our monitoring of astronauts over time. Each cohort will provide a complement of three comparison subjects to one astronaut who will be matched on gender, age, and selection date to ensure the cohorts are comparable.

The aim of these studies is to understand the longitudinal occurrence of different types of cardiovascular diseases such as hypertension, atrial fibrillation (and other arrhythmias), and myocardial infarction (heart attack) in the astronaut corps. The occurrence of these will then be compared to the two external cohorts to understand if the incidence of disease is higher or lower among astronauts. Data are currently being compiled from medical records by LSAH epidemiologists and results are forthcoming.

References


³Ade CJ, Broxterman RM, Charvat JM, Barstow TJ: Incidence rate of cardiovascular disease end points in the National Aeronautics and Space Administration Astronaut Corps. J Am Heart Assoc Aug 07, 6(8) https://doi.org/10.1161/JAHA.117.005564

Attached are publications related to LSAH data requests and other papers that may be of interest. For your convenience, each publication has a link according to the Digital Object Identifier (DOI) system, if available, to take you directly to the abstract or publication online. For papers not available via open source, the corresponding author may be able to provide you with a copy.


Ade CJ, Broxterman RM, Charvat JM, Barstow TJ: Incidence rate of cardiovascular disease end points in the National Aeronautics and Space Administration Astronaut Corps. *J Am Heart Assoc* 2017, 6(8). [http://doi.org/10.1161/JAHA.117.005564](http://doi.org/10.1161/JAHA.117.005564)


News and Notes

Travel Tidbits:
For those traveling from out of town to JSC for your annual LSAH physical examination, here are some important facts to keep in mind when making your arrangements. Reimbursements are made for the following:

♦ Nonrefundable air fare using economy or coach fare on any airline. Reimbursement rates are usually based on Southwest Airlines, “Wanna Get Away (WGA)” fare cost.
♦ Compact or intermediate class rental cars
♦ Government hotel per diem rate for 2018 is $137 plus tax.
♦ If you choose personal car or plane transportation, you will be reimbursed based at the lower rate of either the economy/coach/WGA fare or the mileage rate (0.535 per mile).

You may book your choice of airfare, or rental car, but as a NASA contractor, KBRwyle can only reimburse you according to Federal regulations. Original receipts must be submitted to process your reimbursement. You will receive a full outline of all travel tips two months prior to your birthday. Contact Denise Patterson at 281-244-5195 or at denise.a.patterson@nasa.gov for any travel questions.

Coffee with CB
The Astronaut Office would like to keep you informed about office happenings, and hear what you’re up to. If you would be interested in meeting with some fellow astronauts over coffee or lunch while in Houston for your annual exam, please contact Karen Nyberg directly: [redacted]. For confidentiality reasons, the Clinic does not tell CB your exam date, so please let Karen know of your interest in meeting as early as possible once you know your exam date.

Astronaut Reunion 2017
The Astronaut Reunion will be held on December 14-15, 2017. On Thursday morning, December 14th, Dr. Renak Shah, the JSC Clinic Medical Director, will provide updates on Space Medicine Operations and the TREAT Astronauts Act. We hope you can attend.

Medical Records:
As the TREAT Astronauts Act signifies, the long-term health of our retired astronauts is critical to understanding occupationally-related medical outcomes and how our ‘healthy population’ ages. If you are interested in sharing this important information with us, please work with Denise to identify external medical providers you have seen since your last exam (not including sick visits). She can request your medical records be sent directly to the JSC Clinic in advance of your exam.

FYI
If you have a new address, phone number, or email please let us know by calling 281-244-5195 or 281-483-7999. You may also write us at:

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