

The background of the slide is a photograph of the International Space Station (ISS) orbiting the Earth. The station is visible in the upper left corner, with its complex structure and solar panels clearly defined against the blackness of space. The Earth's surface is shown as a curved horizon with a blue sky and white clouds. The title text is overlaid on this image.

# **Cervical Spine Intervertebral Disc Herniation on board the International Space Station: Diagnosis, Treatment and Operational Mission Impact**

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**UTMB Aerospace Medicine Grand Rounds**

**11 July 2023**

UTMB Aerospace Medicine GR 2023



# Disclosure Information

*Richard A. Scheuring, DO, MS*  
*Danielle N. Anderson, DPT, DSc*

- We have no financial relationships to disclose.
- We will not discuss off-label use and/or investigational use in our presentation
- Views presented are our own and do not reflect the views of NASA, the US Government, DoD, or UTMB...



93rd Annual Aerospace Medicine Scientific Meeting, New Orleans, LA  
24-May-2023



# Overview

- A healthy RHD 55-year-old astronaut has developed an acute right-sided neck pain extending into the right arm with paresthesia and weakness four months into his long duration space flight on the International Space Station (ISS)...
  - You're 24 hours from going out the hatch for a planned PET 7:00 Extravehicular Activity (EVA)
  - How do you make the diagnosis?
  - What are your treatment options?
  - What do you tell the NASA chief medical officer (CMO), mission planners, flight directors, crew member's family, and ISS Program managers?



Start of USOS EVA 45 during ISS Exp 53 10-Oct-2017.  
Source: iss053e095650.jpg @ nasa.gov.



# Overview

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- There was no prior h/o cervical spine issues in this individual
- At the time of mission assignment, there was no requirement for spinal imaging for screening purposes
- Prior to the gradual onset of symptoms, crew member had been performing all required on-board activities and exercise
- There was no apparent mechanism of injury (MOI) on the ISS



# Overview

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- Human space flight poses unique challenges to the diagnosis, treatment, and monitoring of medical conditions
  - Discuss Diagnosis & Treatment
  - Operational Mission Impacts
  - On-orbit Musculoskeletal (MSK) Rehabilitation
  - Spinal Pathophysiology
  - Disposition



# 64S...

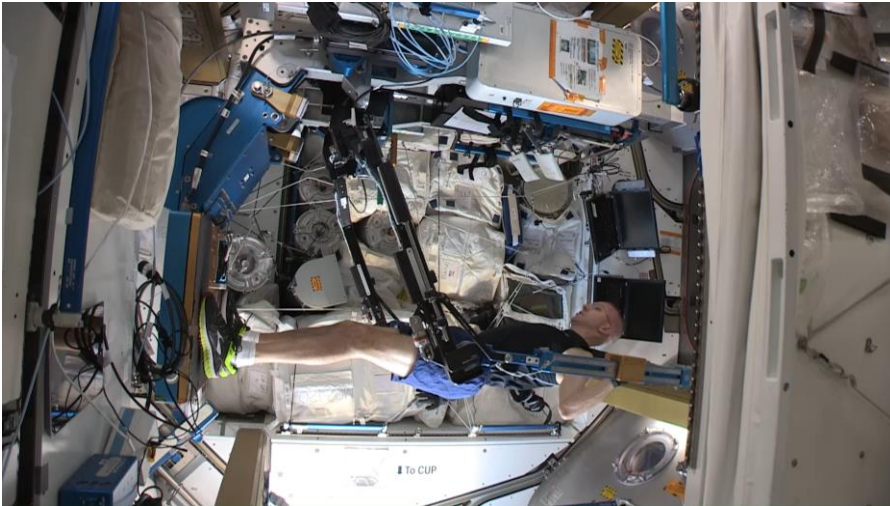
- 9 April 2021- Launch



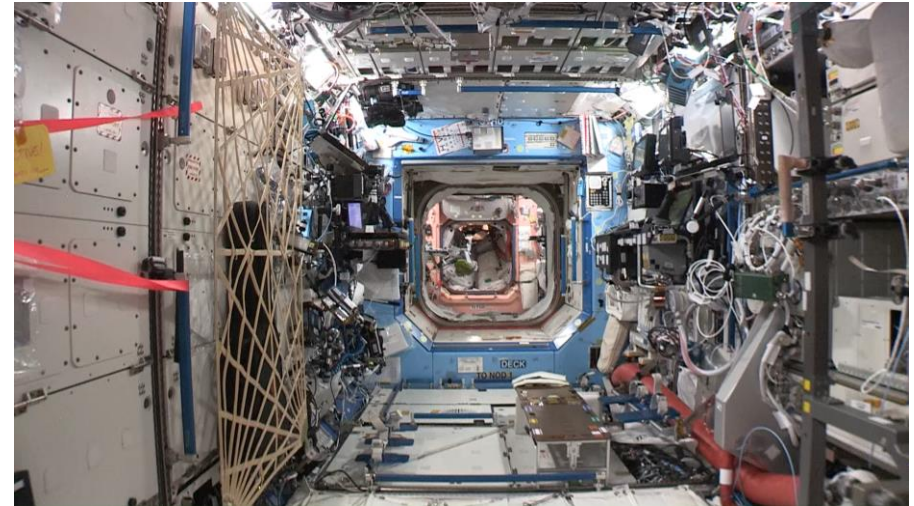


# Primer on On-Orbit Exercise Countermeasures

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ISS Exp 53 CDR Randy Bresnik demonstrating **ARED** Exercises on ISS, November 2017

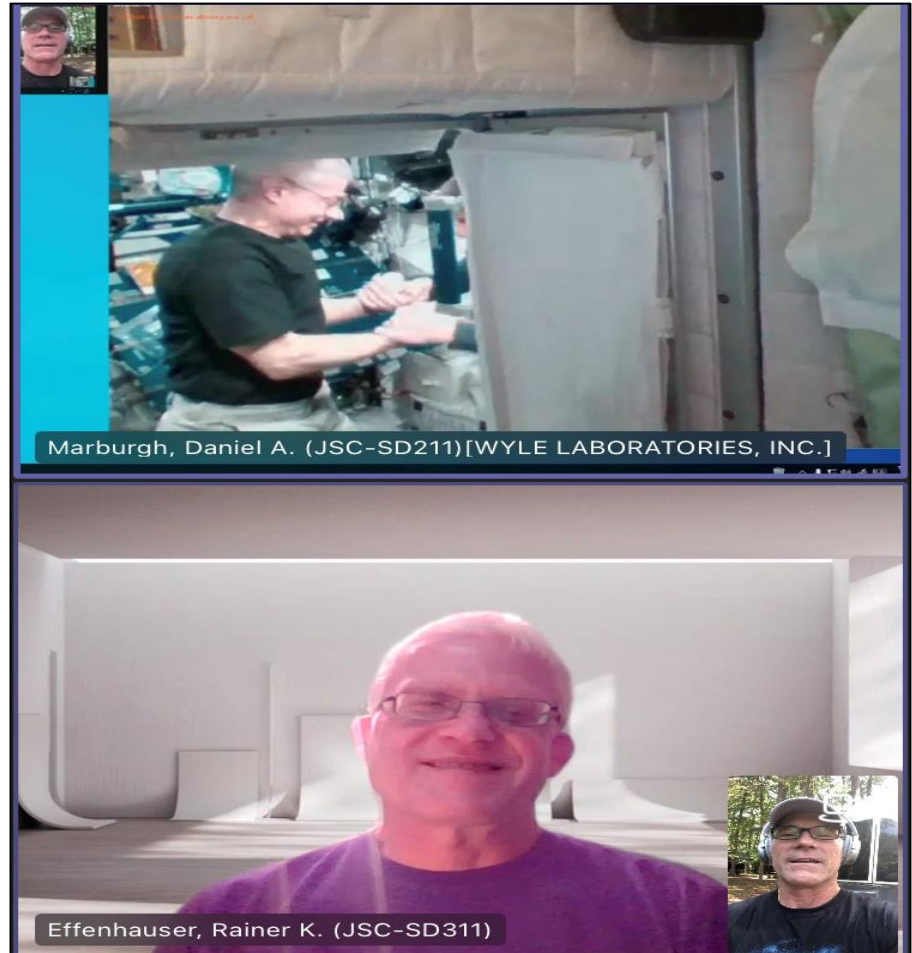


ISS Exp 53 CDR Randy Bresnik demonstrating running on the "T2" treadmill in Node 3, ISS, November 2017.



# Diagnosis & Treatment

- June 2021- Onset mild right medial elbow pain with grabbing hand holds during translation
  - Differential diagnosis
    - Medial epicondylitis
    - Common flexor tendon strain
    - Ulnar collateral ligament sprain
    - Ulnar nerve subluxation
    - Cubital tunnel syndrome



Remote Audio-Visual Private Medical Conference (PMC) via Teams





# Diagnosis & Treatment



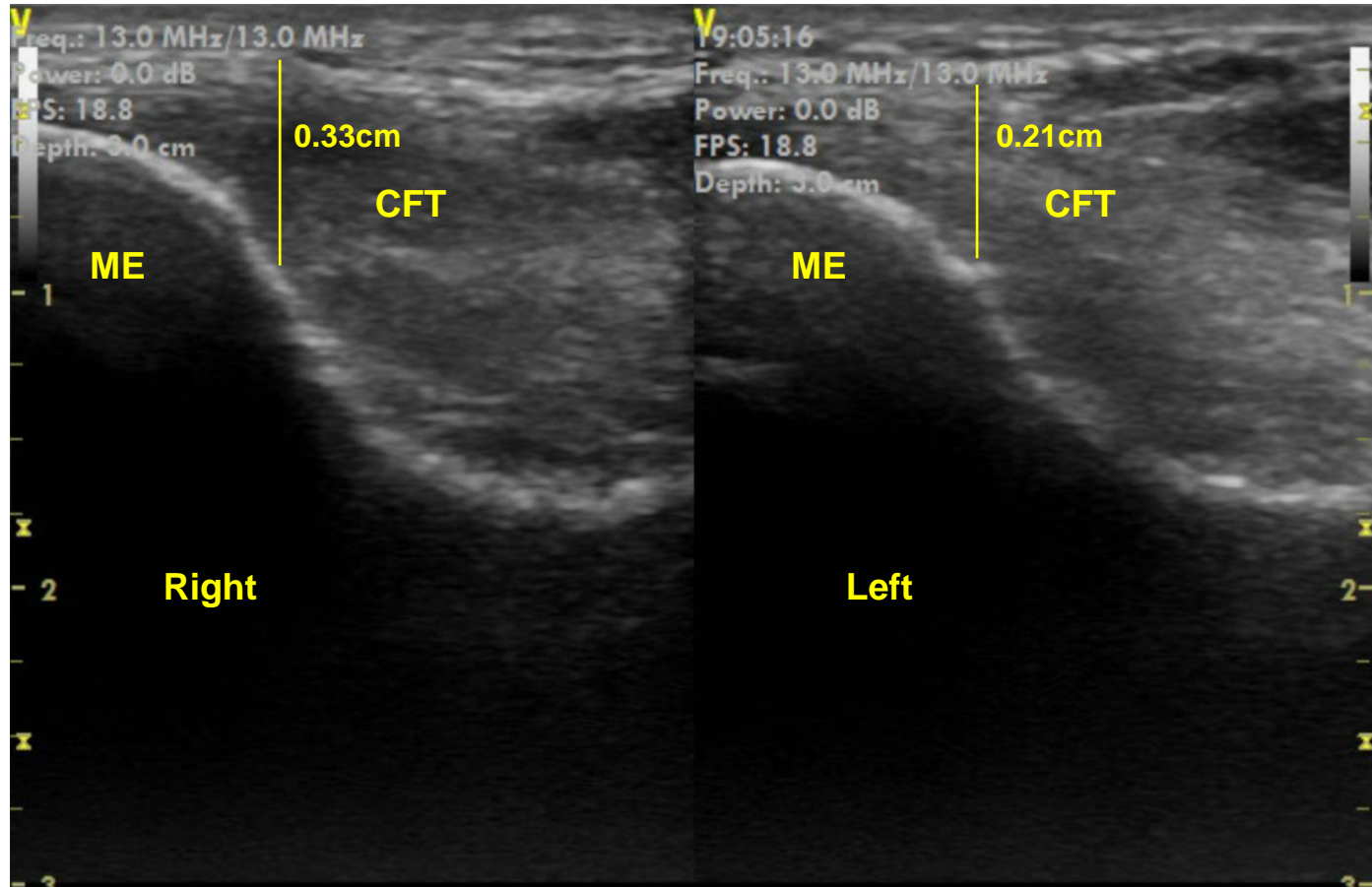
NASA-JSC Telemedicine operations center, Mission Control Center, Houston, TX



Remotely guided MSK Ultrasound of the right medial elbow



# MSK Ultrasound from ISS





# Initial Treatment for Medial Epicondylitis

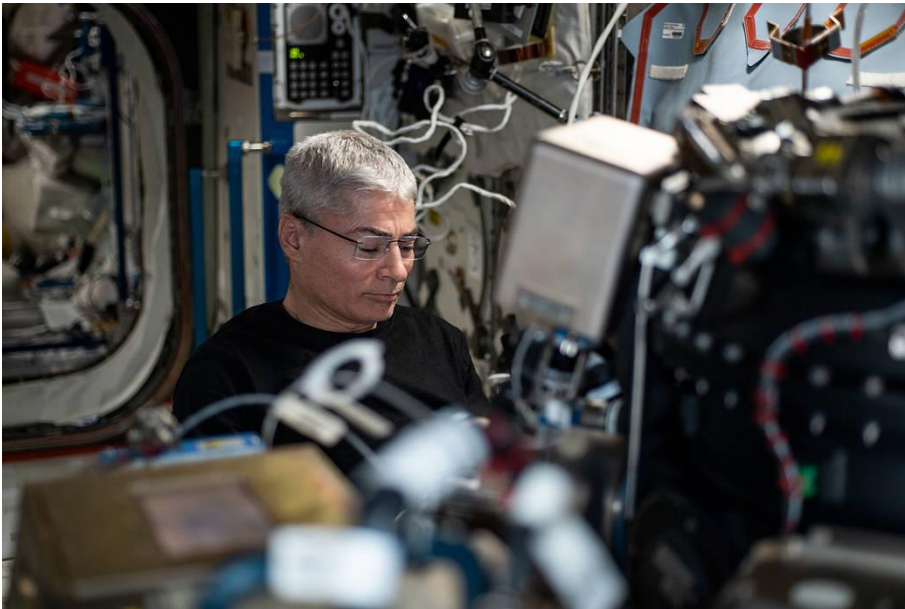
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- Rx w/ topical diclofenac gel 1%, relative rest/exercise and activity modification; Frequent comms/status via email, PMCs, Private Exercise Conferences (PECs).
- Approximately 3-4 weeks after initial diagnosis symptoms were 70-75% improved



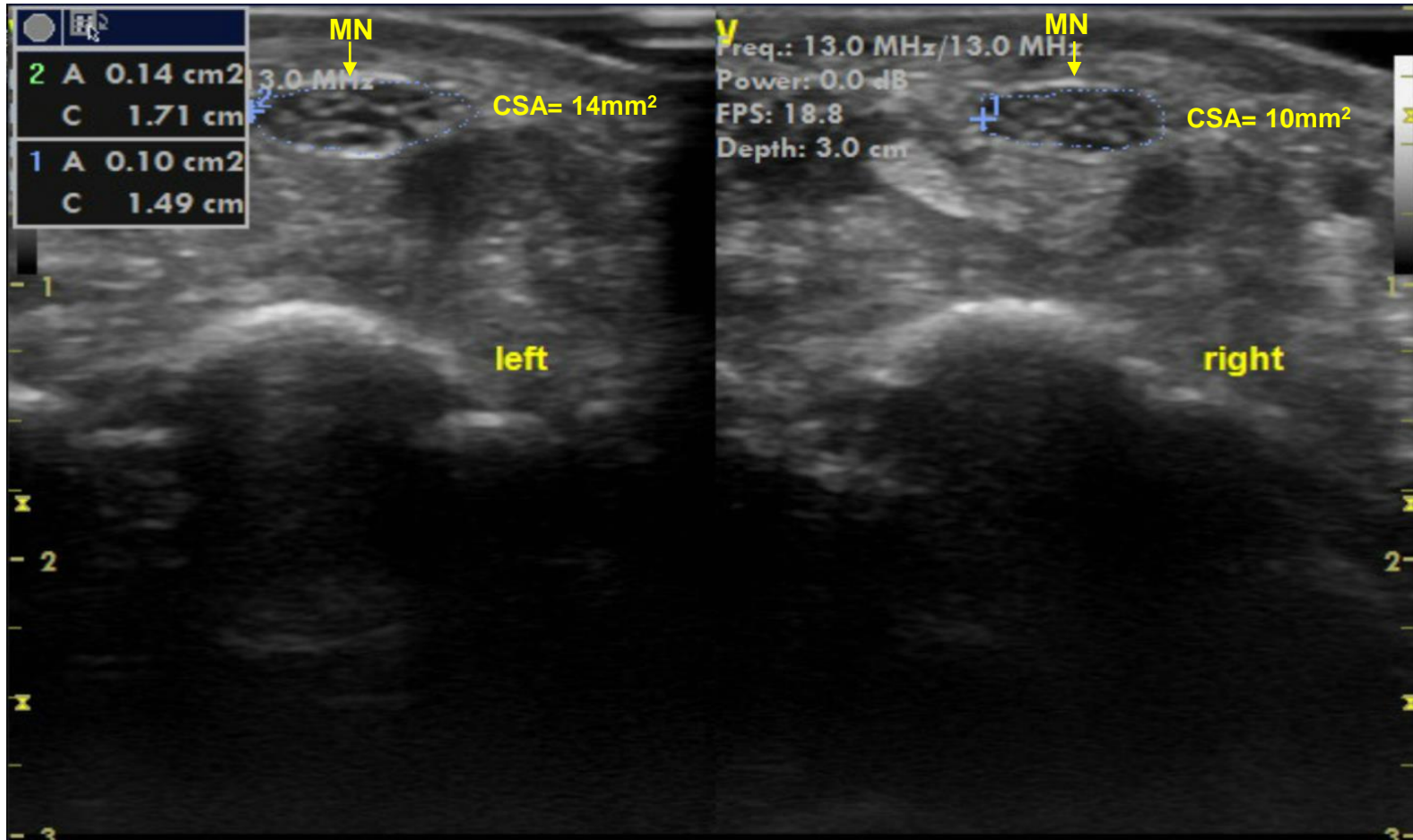
# Diagnosis & Treatment

- Approximately 4 months into ISS Expedition 64...





# Median Nerve Evaluation



Comparison short axis view (SAX) US of the median nerve (MN) at the proximal carpal tunnel with cross sectional area (CSA) measurements of both left and right nerves.



# Initial Treatment for CTS

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- Rx w/ oral steroids, Rest/Exercise Modification; Frequent comms/status via email, PMCs, Private Exercise Conferences (PECs)
- Feedback on 14-Aug was that paresthesia improved, scapular pain lessened, overall improving



# Case Progression

- 20 August 2021- Onset Right Triceps weakness, worsened hand paresthesia; (Notified Surgeon late 22 August):

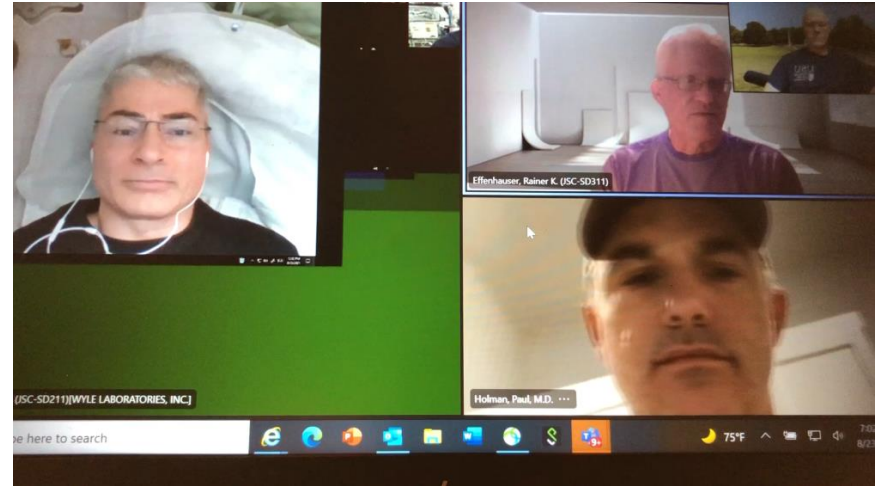
*“I think that on Friday (whatever day involved recording of my ARED session), I noticed while doing Cable Triceps Extensions that my right arm didn’t seem to be getting recruited as much as I’d like. Without changing the weight, I used my left arm to see if I could do a rep. I could move the bar a couple of inches. I then tried with my right arm and couldn’t budge it.”*

DATE	Triceps Extension	Notes
20 August 2022	L: Normal, R: unable	20 lbs.
21 Aug 2022	13 reps L, 2 reps R	20 lbs.
22 Aug 2022	Notified Surgeons of Weakness by email	



# Unscheduled Private Medical Conference (PMC)

- 23-Aug-2021 PMC:
  - Realtime neurological exam with our neurosurgical/ortho spine surgical consultants
  - Clinical hx, PEX c/w acute C6/7 HNP with C7 radiculopathy including motor weakness of the triceps







# Forward Plan

- Decision to defer participation on 24-Aug EVA
- Begin relative rest, repeat Medrol dose pack, short-acting BZP for muscle spasm, modified exercise program
- Develop on-orbit cervical spine and triceps muscle US procedure

← Tweet

 **Mark T. Vande Hei**    
@Astro\_Sabot

Thanks for everyone's concern. I have a pinched nerve in my neck that caused us to reschedule today's spacewalk. The support from family, friends, and NASA leadership has been fantastic. I'm looking forward to installing this IROSA Mod kit. Today just wasn't the right day.

 **International Space Station**   @Space\_Station · Aug 23, 2021

The spacewalk preview briefing today at 2 pm ET and tomorrow's spacewalk have been postponed. For further updates, please visit [blogs.nasa.gov/spacestation/](https://blogs.nasa.gov/spacestation/).



ALT

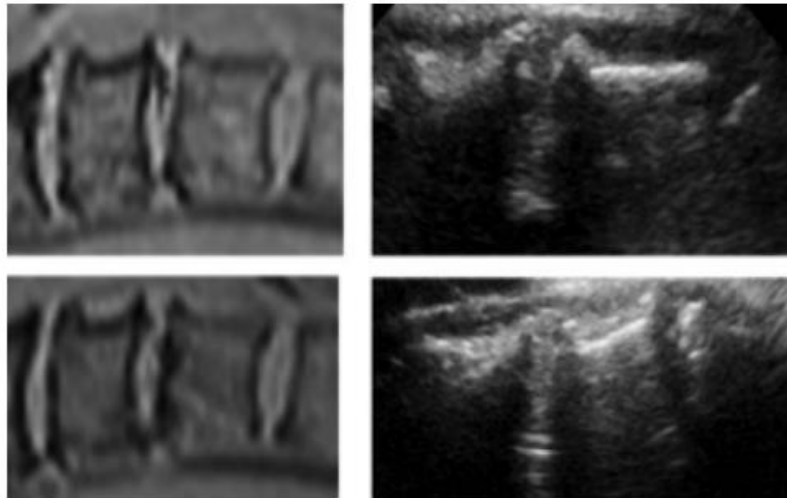
10:30 AM · Aug 24, 2021

208 Retweets 45 Quotes 2,310 Likes 8 Bookmarks



# Pioneering Spine Ultrasound in Space

**Figure 10.** Osteophytes shown before (top) and after (bottom) flight on MRI and US images of the cervical spine in C4-5 and C5-6. The US images look slightly more retracted, but the irregularity remains.



## Real-time Ultrasound Assessment of Astronaut Spinal Anatomy and Disorders on the International Space Station

Kathleen M. Garcia, BSc, Michael F. Harrison, MD, PhD, Ashot E. Sargyan, MD, Douglas Ebert, PhD, Scott A. Dulchavsky, MD, PhD

**Objectives**—Back pain is one of the most common conditions of astronauts during spaceflight and is hypothesized to be attributed to pathologic anatomic changes. Ultrasound (US) represents the only available imaging modality on the International Space Station, but a formal US protocol for imaging the structures of the spinal column does not exist. This investigation developed a method of acquiring diagnostic-quality images of the anterior lumbar and cervical regions of the spine during long-duration spaceflight.

**Methods**—Comprehensive spinal US examinations were conducted on 7 long-duration spaceflight astronauts before flight, in flight, and after flight and compared to preflight and postflight magnetic resonance imaging data. In-flight scans were conducted after just-in-time training assisted by remote expert tele-US guidance.

**Results**—Novice users were able to obtain diagnostic-quality spinal images with a 92.5% success rate. Thirty-three anomalous or pathologic findings were identified during the preflight US analysis, and at least 14 new findings or progressions were identified during the postflight US analysis. Common findings included disk desiccation, osteophytes, and qualitative changes in the intervertebral disk height and angle.

**Conclusions**—Ultrasound has proven efficacy as a portable and versatile diagnostic imaging modality under austere conditions. We demonstrated a potential role for US to evaluate spinal integrity and alterations in the extreme environment of space on the International Space Station. Further investigations should be performed to corroborate this imaging technique and to create a larger database related to in-flight spinal conditions during long-duration spaceflight.

**Key Words**—astronaut; cervical spine; lumbar spine; microgravity; musculoskeletal; point of care; spine; sonographer issuer; sports medicine/orthopedics; ultrasound techniques/physics

Received March 24, 2017, from KRBBoyle, Houston, Texas USA (KMBG, A.E.S., D.E.), and Departments of Emergency Medicine (M.F.H.), Internal Medicine (M.F.H.), Critical Care Medicine (M.F.H.), and Surgery (S.A.D.), Henry Ford Hospital, Detroit, Michigan USA. Manuscript accepted for publication July 18, 2017.

We thank the astronauts and the International Space Station Medical Project implementation team members who participated in and supported this project. This research was supported by the National Aeronautics and Space Administration (NASA) through NASA grant NNX16OAM34G.

Address correspondence to Scott A. Dulchavsky, MD, PhD, Department of Surgery, Henry Ford Hospital, 2799 W Grand Blvd, Detroit, MI 48202 USA.

Email: sdulchav@fhhs.org

**Abbreviations**  
ISS, International Space Station; MRI, magnetic resonance imaging; NASA, National Aeronautics and Space Administration; US, ultrasound

doi:10.1002/jum.14438

© 2017 by the American Institute of Ultrasound in Medicine | J Ultrasound Med 2018; 37:987-999 | 0278-4297 | www.aium.org

J of Ultrasound Medicine, Volume: 37, Issue: 4, Pages: 987-999, First published: 29 September 2017, DOI: (10.1002/jum.14438)



# Procedure development

xxxxxxxxx ULTRASOUND IMAGING- SPINE  
(XXXXXX)

Page 3 of 13 pages



Figure 3.- Alternate CMRS/Subject/Operator position for CMRS attached to seat tracks on forward wall (not shown).

Position CMRS against forward wall and attach to seat tracks (Figure 3)

- 1.3 Configure restraint device(s) of choice if desired (i.e., foot loops, bungees, CMRS, etc.) in preparation for maintaining stability of subject and operator during scan. Restraint configuration should prevent any spinal movement of the subject to avoid inadvertent contraction of the back musculature during the scan unless directed by remote guider.

## 2. INSTALLING ULTRASOUND 2 PROBE

24 OCT 19

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xxxxxxxxx ULTRASOUND IMAGING- SPINE  
(XXXXXX)

Page 4 of 13 pages

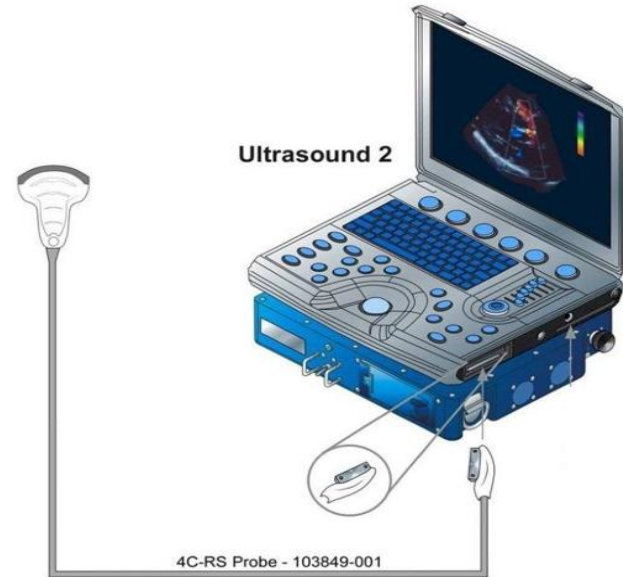


Figure 4. – 4C-RS Probe Cabling Diagram.

24 OCT 19

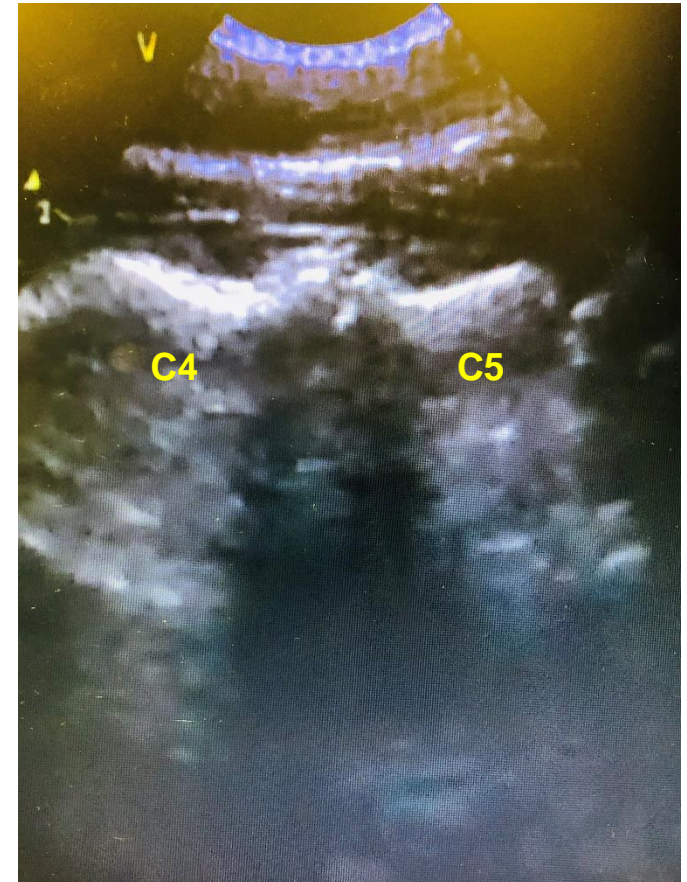
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# Cervical Spine US on ISS



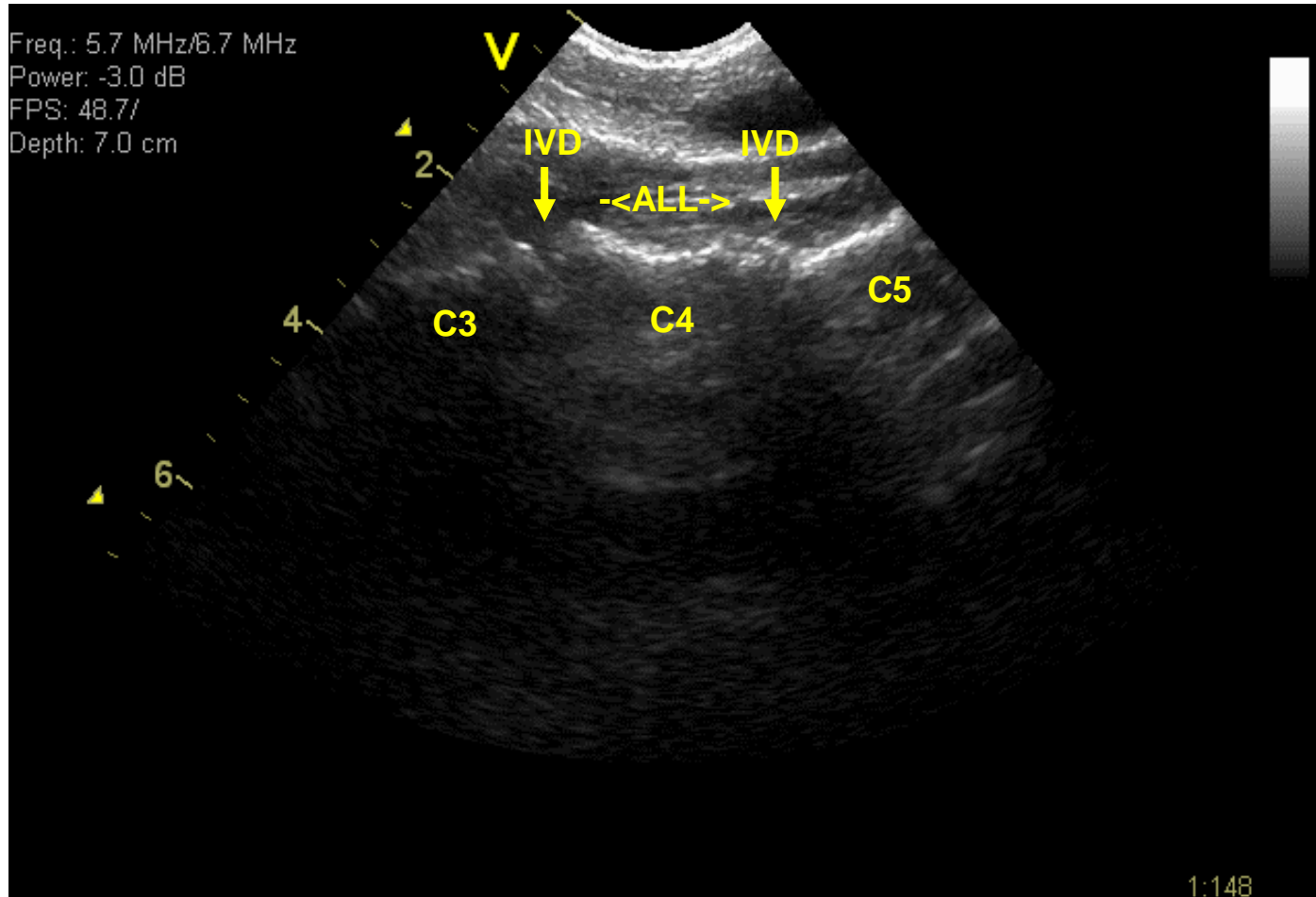
Cervical spine US procedure development and verification at NASA-JSC, 26-Aug-2021



Cervical spine US procedure execution on ISS, 27-Aug-2021 in Columbus module. Image of C4/5 in LAX.



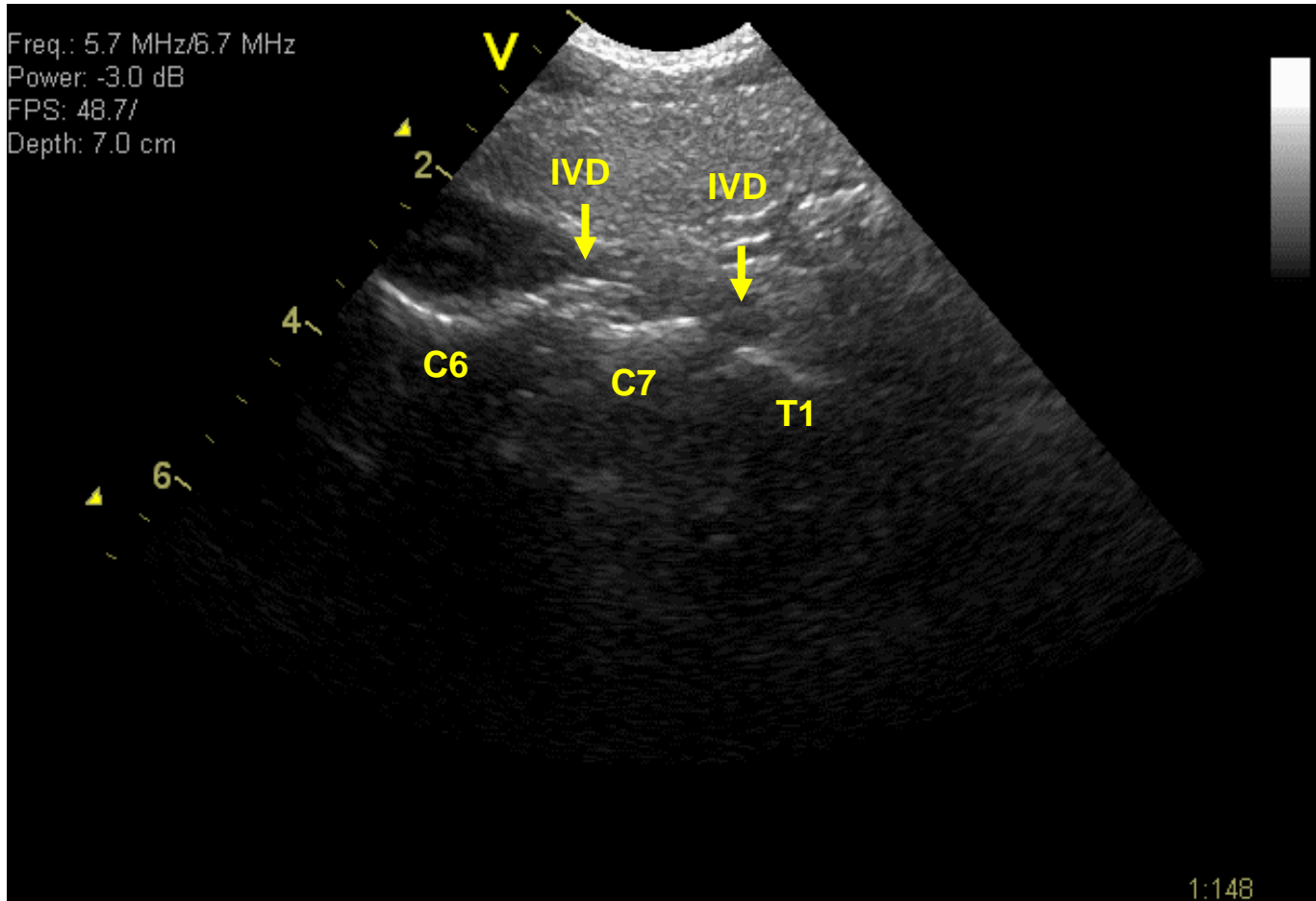
# Cervical Spine US on ISS



US scan of C4/5 and C5/6 in LAX, 27-Aug-2021.



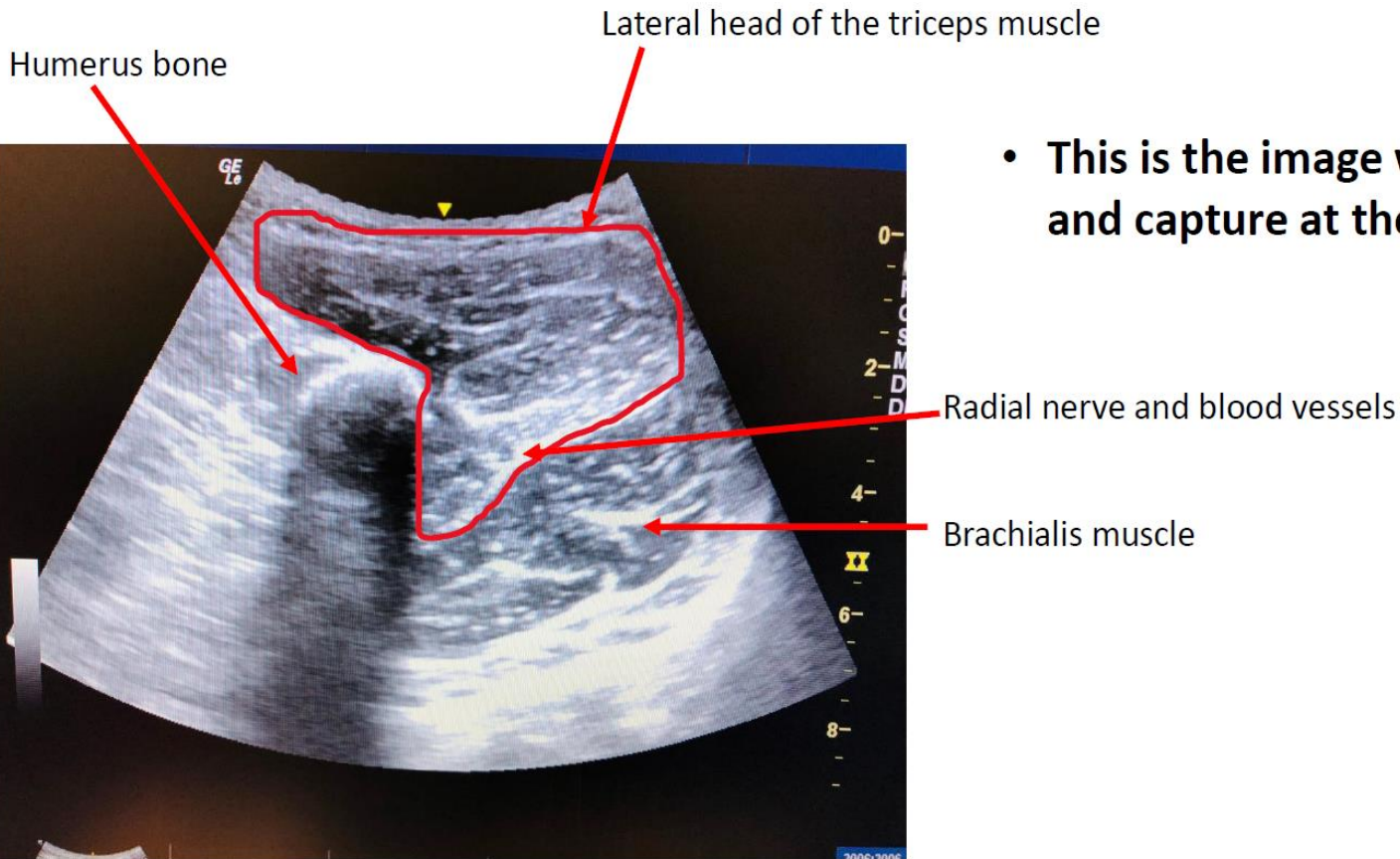
# Cervical Spine US on ISS *cont'd...*



US scan of C6/7 and 7/T1 in LAX, 27-Aug-2021.



# Procedure development

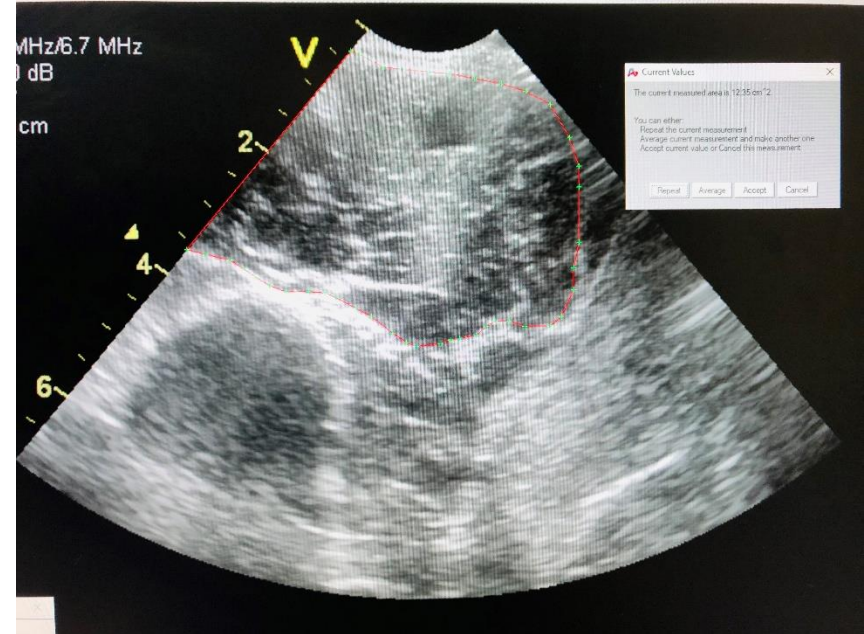


- This is the image we want to try and capture at the muscle belly



# Triceps Evaluation

- Baseline triceps muscle measurements taken with left side comparison views

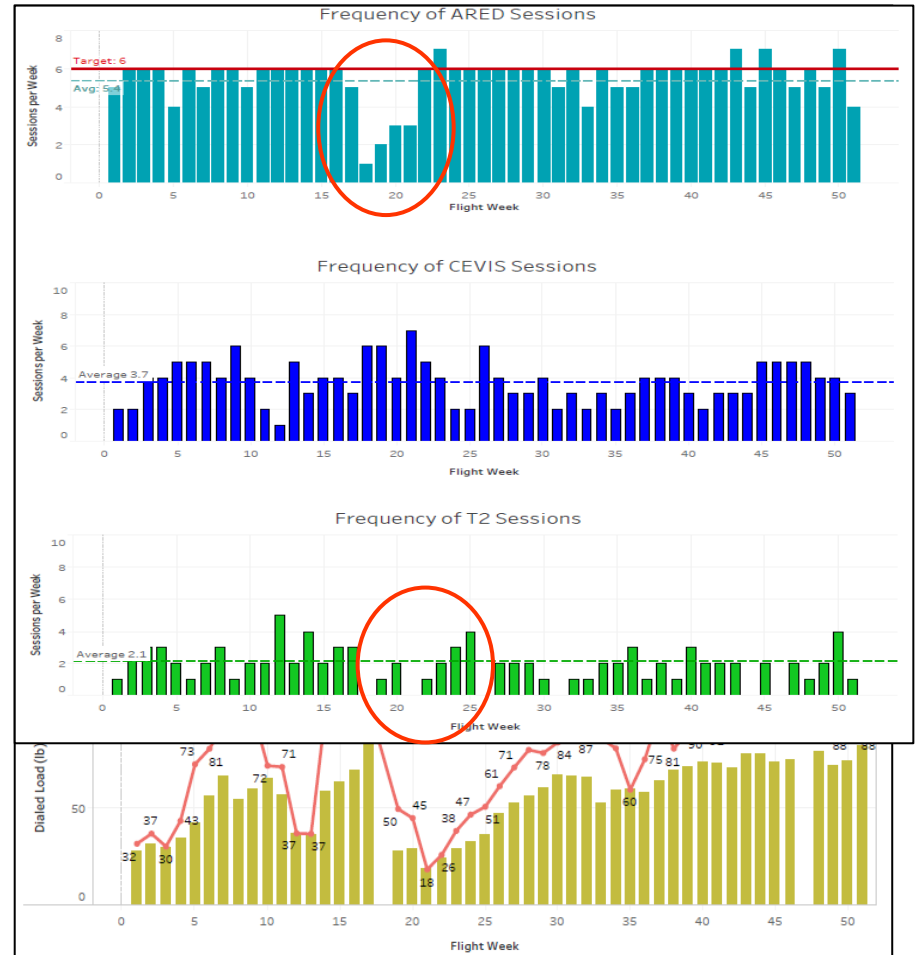






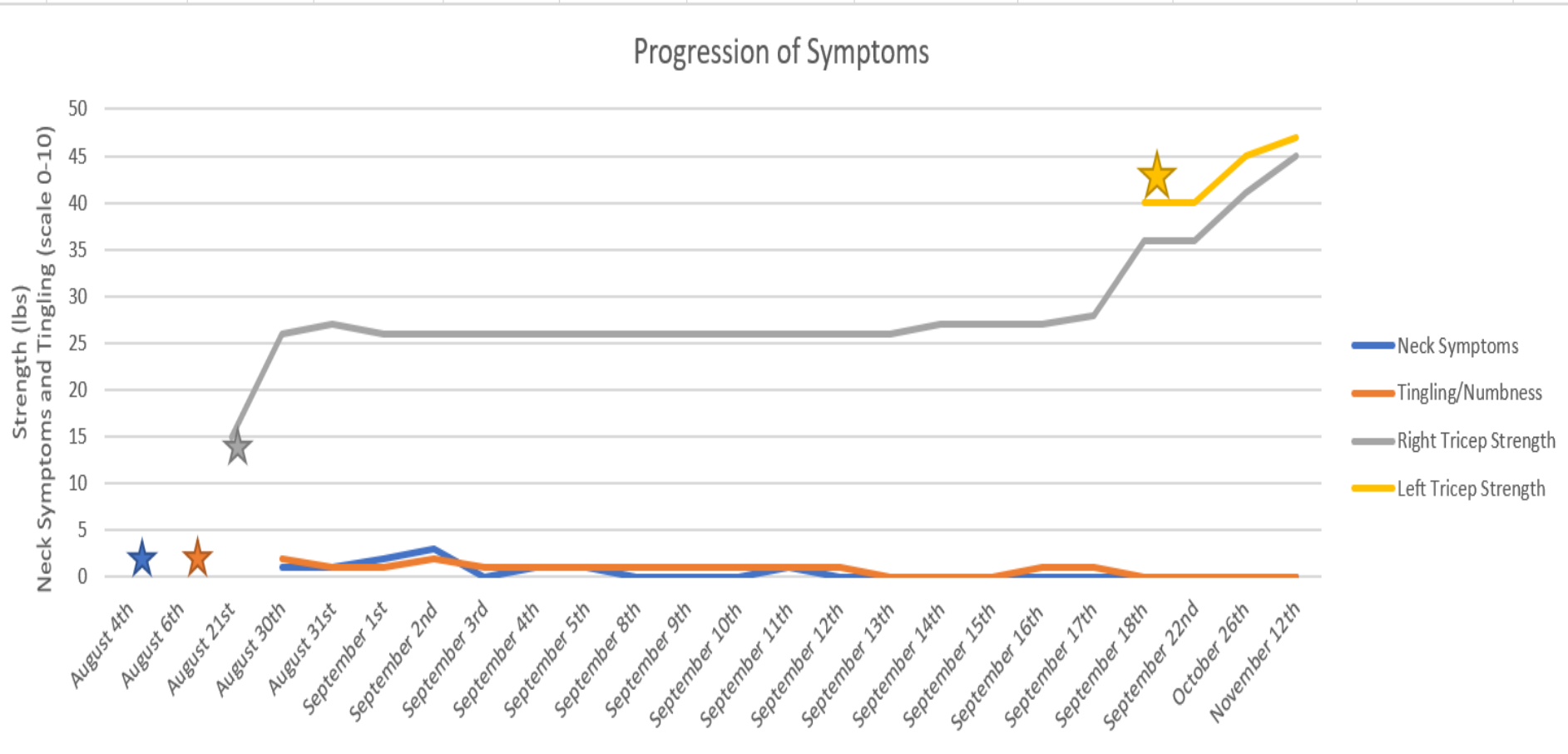
# Objective Exercise Impacts

- Trends in resistive (ARED) and T2 treadmill exercises before, during the acute injury and rehabilitation phase





# Diagnosis & Treatment





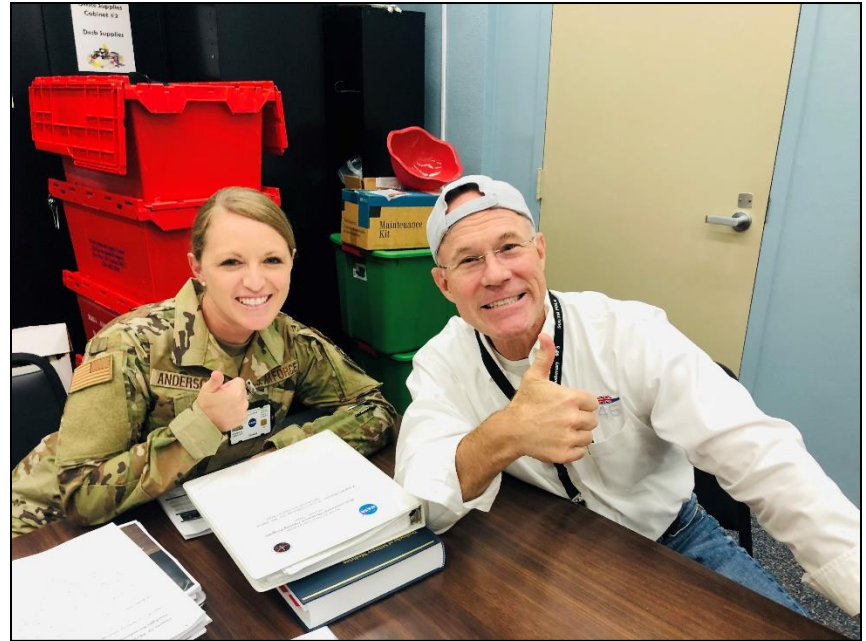
# Exercise alternatives





# Forgot to mention...

- Maj Danielle Anderson, DPT, joined the NASA MSK Medicine and Rehab team on 25-Aug-2021...



Maj Danielle Anderson, welcome to NASA! 25-Aug-2023



# Transition to On-Orbit Rehab...





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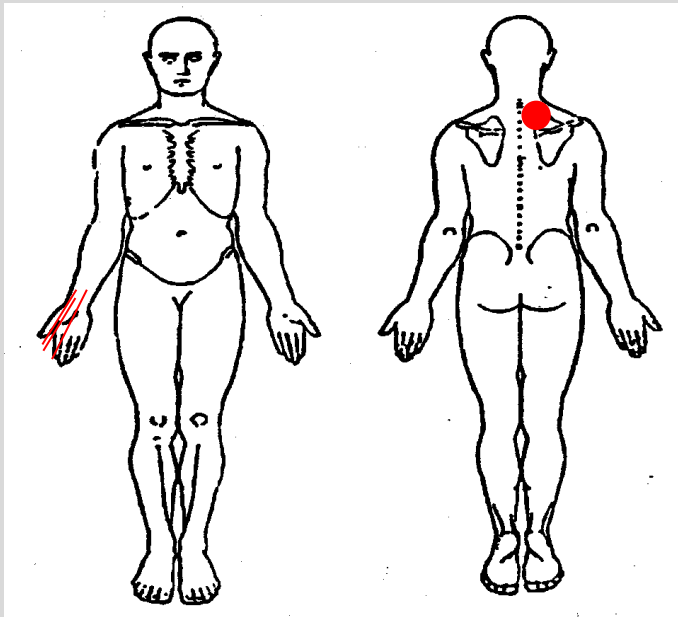
# Outline

- **Case Description**
- **Evidenced Based Decision making for Cervical Radiculopathy**
- **On-orbit rehab program and outcomes**
- **Post-fight considerations**



# Clinical Examination

55 y/o male w/sharp scapular pain and numbness/tingling in to the 1-3<sup>rd</sup> digits



## Key Subjective Findings:

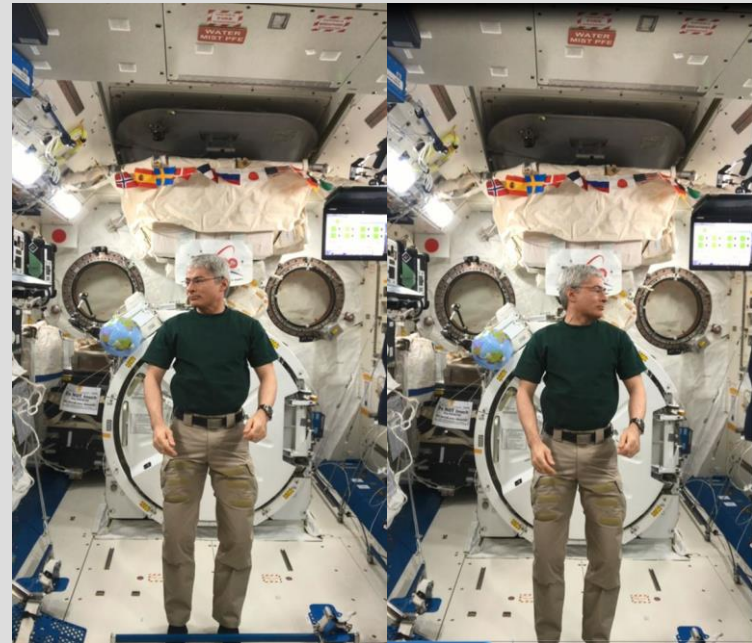
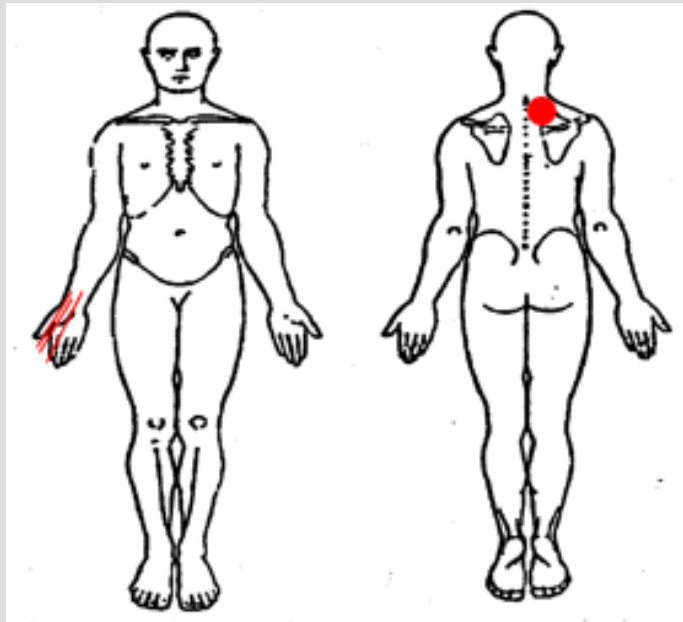
- P1 (scapular pain) present with shaving
- P2 (N/T in 1-3<sup>rd</sup> digits) increases with axial loading
- Notable weakness in the right triceps muscle when performing ARED
- Reported Right external Jugular vein swelling
- Previously pain in medial elbow and intermittent N/T in the 4<sup>th</sup> and 5<sup>th</sup>

Young IA, Phys Ther, 2010



# Clinical Examination

55 y/o male w/sharp scapular pain and numbness/tingling in to the 1-3<sup>rd</sup> digits



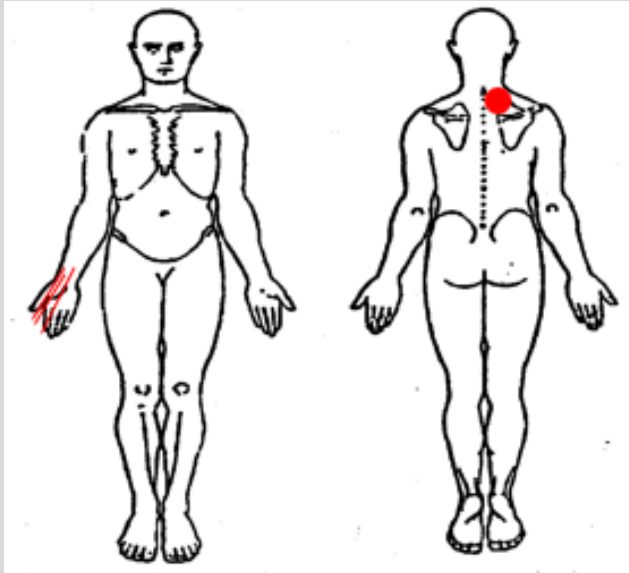
Young IA, Phys Ther, 2010





# Clinical Examination

55 y/o male w/sharp scapular pain and numbness/tingling in to the 1-3<sup>rd</sup> digits

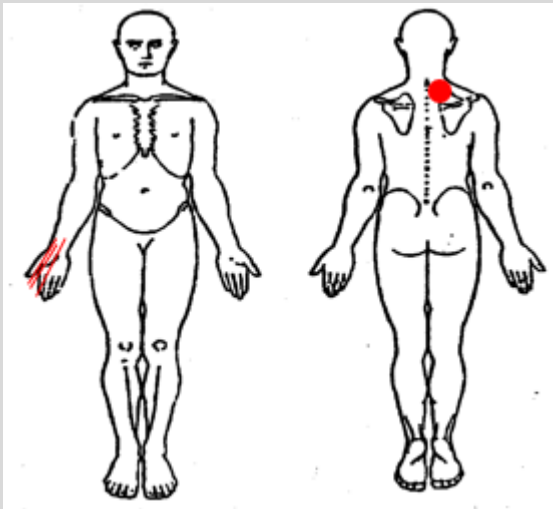


Young IA, Phys Ther, 2010



# Clinical Examination

55 y/o male w/sharp scapular pain and numbness/tingling in to the 1-3<sup>rd</sup> digits



Young IA, Phys Ther, 2010



# Evidence Based Strategies

## Diagnostic Confidence:

- Positive for all 4 test on Wainner Clinical Prediction Rule for Cervical Radiculopathy (Wainner, et al. 2003)
- Key Treatment factors: resolution of symptoms with left cervical rotation, cervical distraction, and cervical retractions against resistance

<u>Number of Positive Criteria</u>	<u>Sensitivity</u>	<u>Specificity</u>	<u>Pos LR</u>	<u>Neg LR</u>
Two	0.39 (0.16-0.61)	0.56 (0.43-0.68)	0.88 (1.5-2.5)	1.09
Three	0.39 (0.16-0.61)	0.94 (0.88-1.0)	6.1 (2.0-18.6)	0.65
Four	0.24 (0.05-0.43)	0.99 (0.97-1.0)	30.3 (1.7-538.2)	0.77

## Treatment Approach:

- Initial Goals: Resolution of symptoms utilizing exercise in the direction of easing positions
  - AAROM in to left rotation, scalene stretching, cervical retractions progressing resistance
- Longer term goals: Normalize mobility, sensation and strength
  - Progressive mobility and loading through ARED of the upper extremity



# Daily, Impairment Based, Rehab Program

55 y/o male w/sharp scapular pain and numbness/tingling in to the 1-3<sup>rd</sup> digits



Young IA, Phys Ther, 2010



# Biweekly, Impairment Based, Rehab Program

55 y/o male w/sharp scapular pain and numbness/tingling in to the 1-3<sup>rd</sup> digits



**Performed biweekly: 15 second holds on/off repeated for 5 min for both, repeated 10-15 times or until resolution of symptoms completed this approximately 6 weeks**

Young IA, Phys Ther, 2010



# Biweekly, Impairment Based, Rehab Program

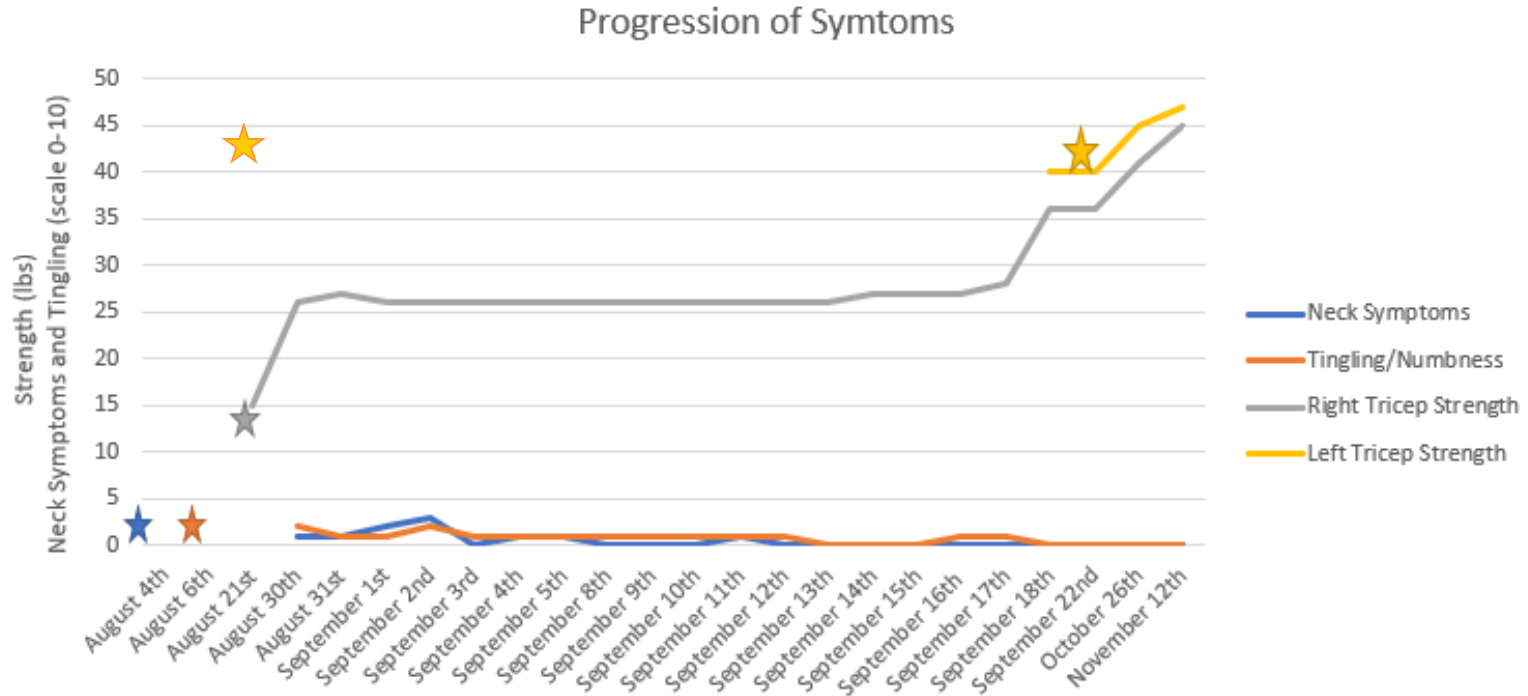


- \* Restraint was performed utilizing the Crew Medical Restraint System (CMRS)
- \* Astronaut physician made variations to place him at a mechanical advantage and resulted in a large upper extremity load to induce desirable forces to the cervical spine

Young IA, Phys Ther, 2010



# Outcomes



EXPEDITION







# SCHEDULE IMPACTS

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- Any major changes to crew activity can cause significant changes to the pre-planned events and a create a large replanning effort across the Program
- Medical Impacts to Timeline, such as Mission Impact PMCs for medical issues can lead to cancellation or delay of critical activities such as Extra-Vehicular Activity (EVA)/Spacewalks
- Crew Scheduled vs. Actual Work time is carefully tracked and monitored



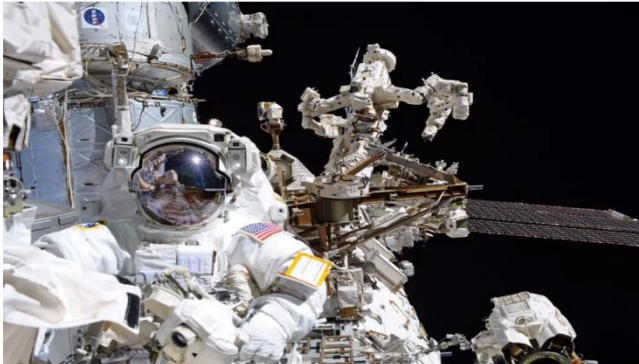
# Clinical Case Status Aug. 2021

SPACE Subscribe Q

**Astronaut medical issue forces NASA to call off spacewalk at space station**  
 By Tariq Malik 5 days ago

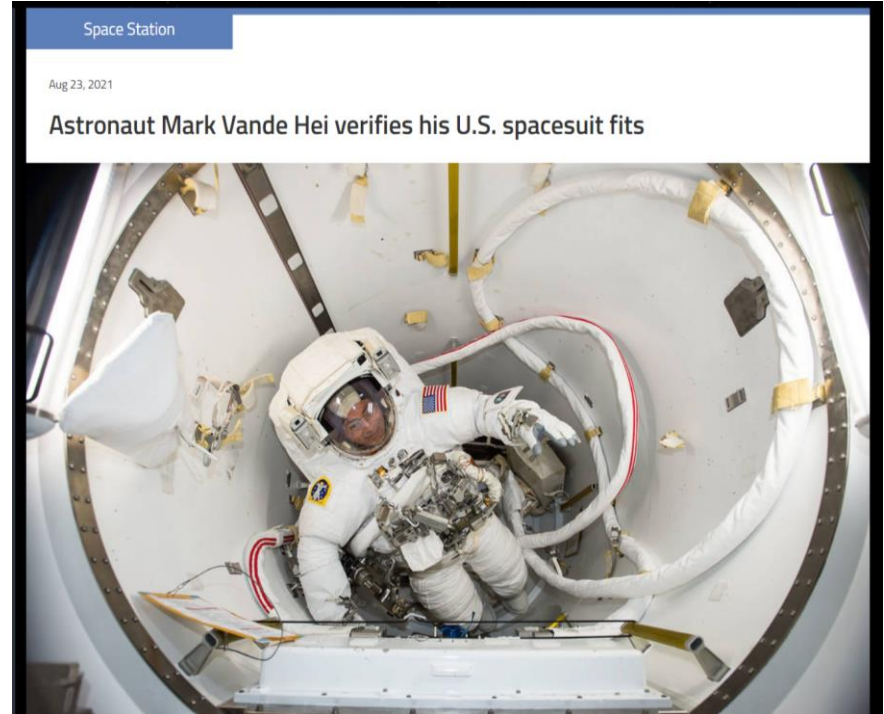
The "minor medical issue" is not an emergency, NASA says.

[f](#) [t](#) [w](#) [g](#) [p](#) [r](#) [m](#)



NASA astronaut Mark Vande Hei on a spacewalk outside the International Space Station in 2017.  
 (Image credit: Randy Bresnik/NASA/Twitter)

NASA has called off plans for a spacewalk outside



Source: Astronaut Mark Vande Hei verifies his U.S. spacesuit fits | NASA.gov

The ISS Program was fully prepped for USOS EVA to install the iROSA Mod Kit with assigned EVA Crew Vande Hei / Hoshide.



# Failure->Impact->Workaround

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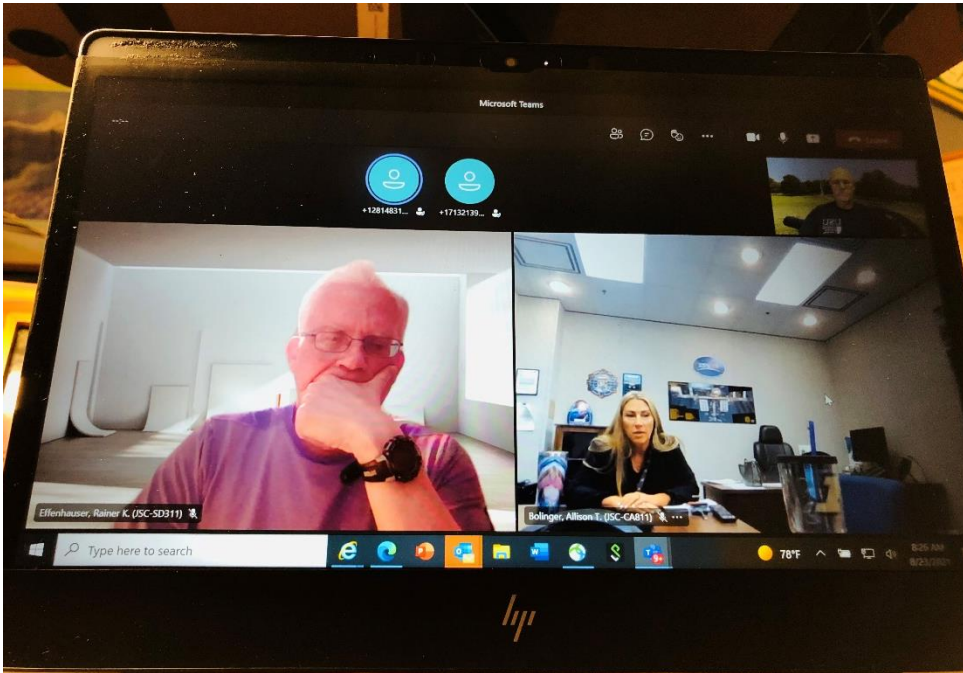
- ISS Program Leads
- Increment Lead FD
- Astronaut Corps Chief
- Chief Medical Officer
  - HQ (Dr. Polk)
  - JSC (Dr. Taddeo)
- OPS PLAN
- Space Medicine Mgt
- Crew's family



ISS053e079156 (Oct. 5, 2017) --- NASA astronaut and Expedition 53 Flight Engineer Mark Vande Hei is pictured during a spacewalk to service components on the Canadarm2 robotic arm during a spacewalk with NASA astronaut Randy Bresnik. Source: nasa.gov



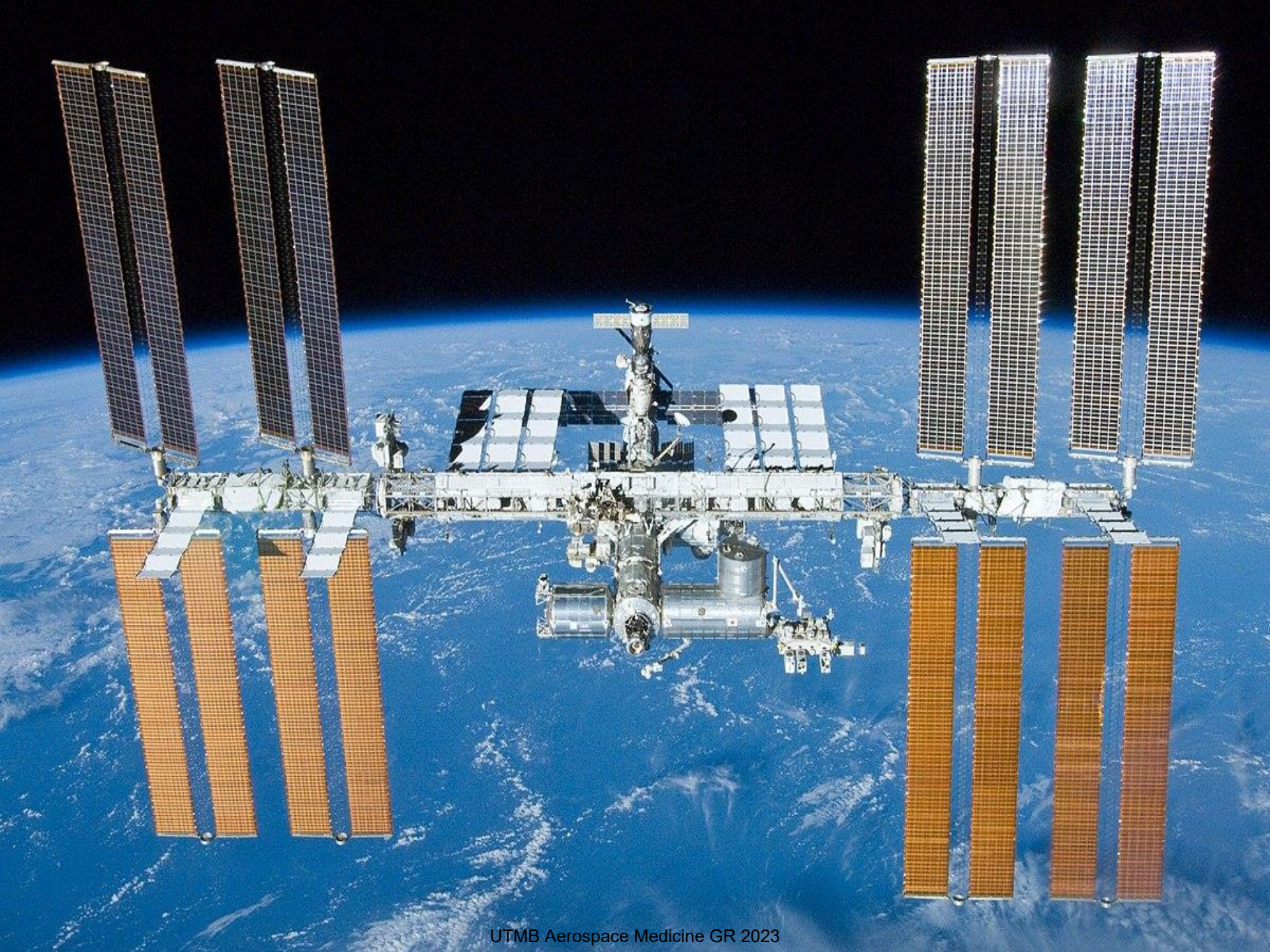
# Mission Impact Medical Event



Exp 64 crew surgeon meeting with ISS Increment Mangement Team, Flight Director, CMO

NASA astronaut Mark Vande Hei on a spacewalk outside the International Space Station in 2017. (Image credit: Randy Bresnik/NASA/<a href=https://twitter.com/AstroKomrade/status/917160822513606656>Twitter</a>)

NASA has called off plans for a spacewalk outside the [International Space Station](#) this week due a medical issue with one of the astronauts due to join the excursion, agency officials said Monday (Aug. 23).





# Case Progression

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- Triceps weakness & Paresthesia resolved by ~October 2021
- Soyuz Landing 30 Mar 2022 (asymptomatic)
- Postflight Imaging (MRI x 2, CT) – see upcoming slides; Neurosurg Consult/Eval;
- Postflight rehab to Present (asymptomatic)



# Landing Preparation



Soyuz seat and Sokul suit evaluation with Russian surgeon and trainer, building 9, NASA-JSC 10-March-2022.



# Cologne, enroute to Karaganda



G5 crew enroute to Karaganda, Kazakhstan via Cologne, GE 25-Mar-2022.





# 65S Landing 30-Mar-2022

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# Landing 30 March 2022

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Dr. Rainer Effenhauser and astronaut Mark Vande Hei, 65S landing, steppes of Kazakhstan, 30-Mar-2022



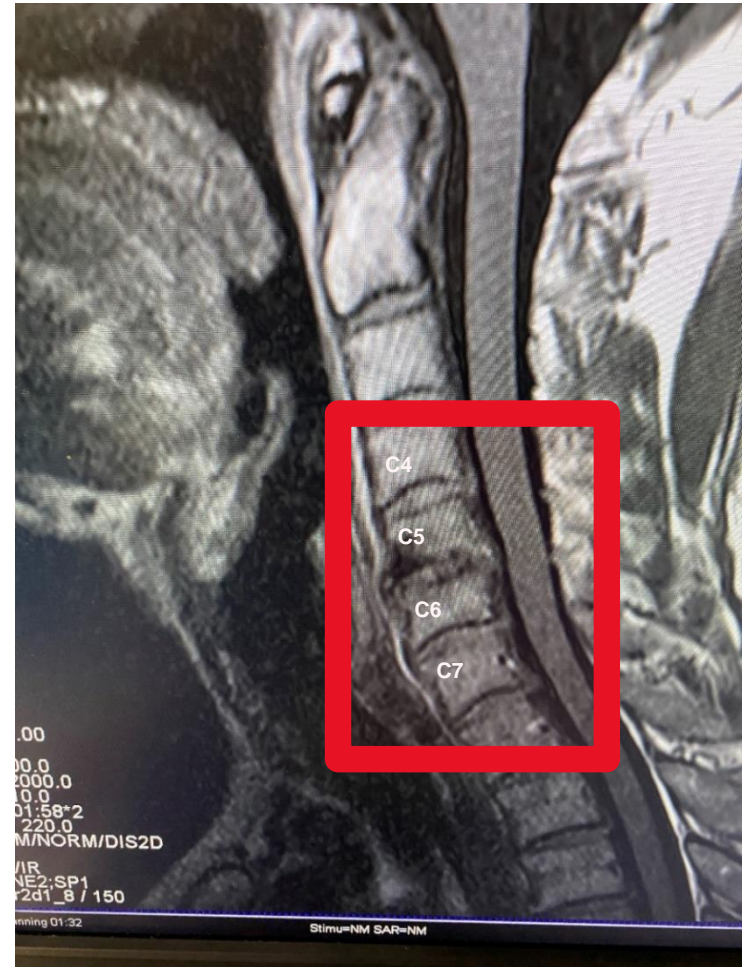
# 30 March 2022



“Green Bay, Green Bay, Green Bay” reported from the 65S LZ, Kazakhstan 30-Mar-2022.



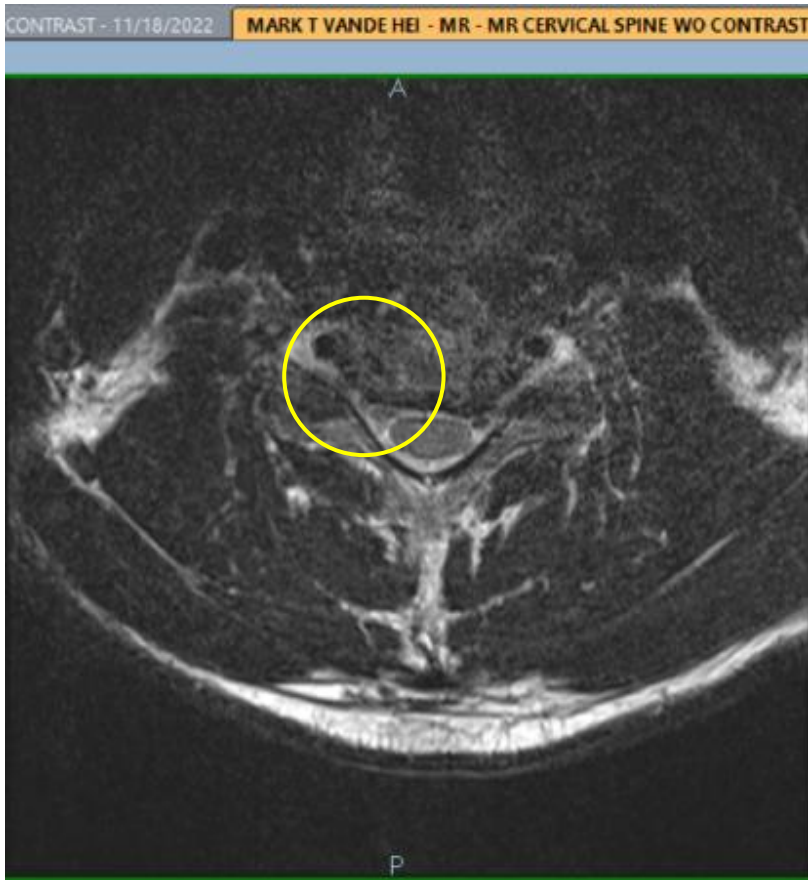
# Cspine MRI 31-Mar-2022





# Cervical Spine MRI 30-Mar-2021

**C5-C6**



**C6-C7**

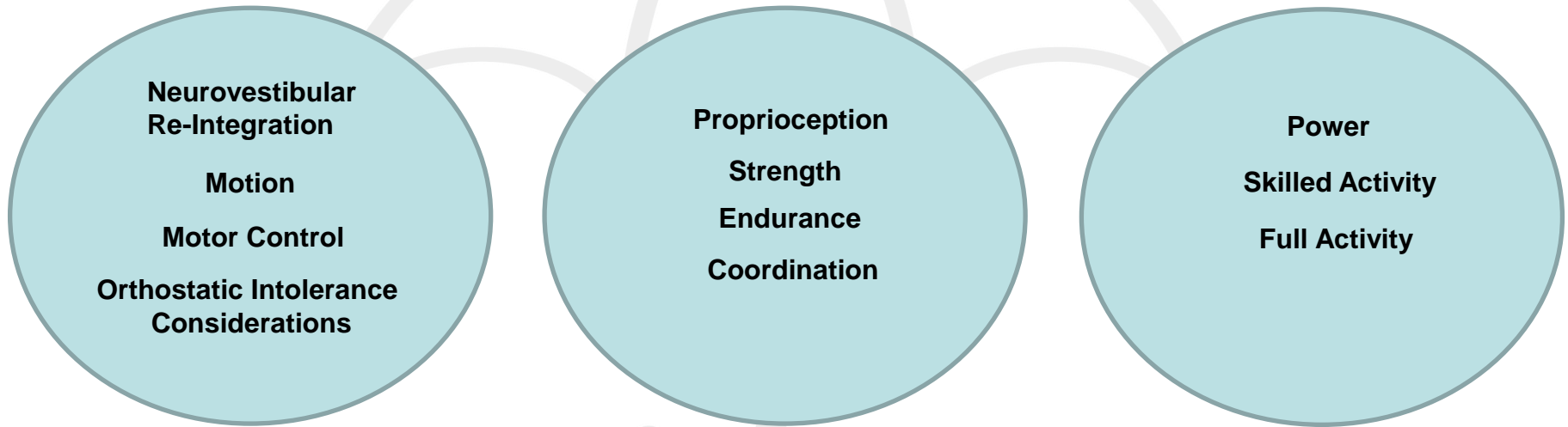




# Post-Flight Reconditioning Considerations

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**Strength, Endurance, Coordination, Mobility, Speed**



1.) Physiologic Effects of Space Flight

2.) Functional Abilities

3.) Crew Members Goals and Training Desires

4.) Other demands (operational, research, etc)



# Post-Flight Considerations

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- **Post Flight Cervical Related Impairments:**

- Limited cervical range of motion (difficulty looking full over the right shoulder)
- Complete resolution of numbness/tingling
- Decreased cervical proprioception
- Decreased deep neck flexor and extensor endurance (craniocervical flexion test-stage 1)





# Rehab Summary

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- Utilizing an evidenced based approach for diagnosis/treatment, combined with Crew Member ingenuity, lead to successful management of a complex cervical radiculopathy
- Consistent and frequent communication and monitoring of symptoms was vital to successful management
- A multimodal, conservative approach, can be accomplished on the Space Station to manage common MSK complaints and should be considered for future long-duration missions
- Symptoms were not provoked on return, however impairments lingered several weeks in to reconditioning
- At the completion of reconditioning, 45 days after return, there was full functional cervical mobility, improved DNF endurance with ability to complete full staged craniocervical flexion protocol, and no subjective complaints of pain or paresthesia






# Post-Flight Completion!!

**WOD**  
WORKOUT  
WORKOUT  
WORKOUT  
WORKOUT

**"SABOT"**  
RFT  
ROW @ 250M  
THRUSTERS @ 75LBS  
REPS 21,15,12,9  
10 KIP-UPS  
10 SIT-UPS  
4 ROUNDS

*This workout can be scaled back. See ASCR staff for questions*





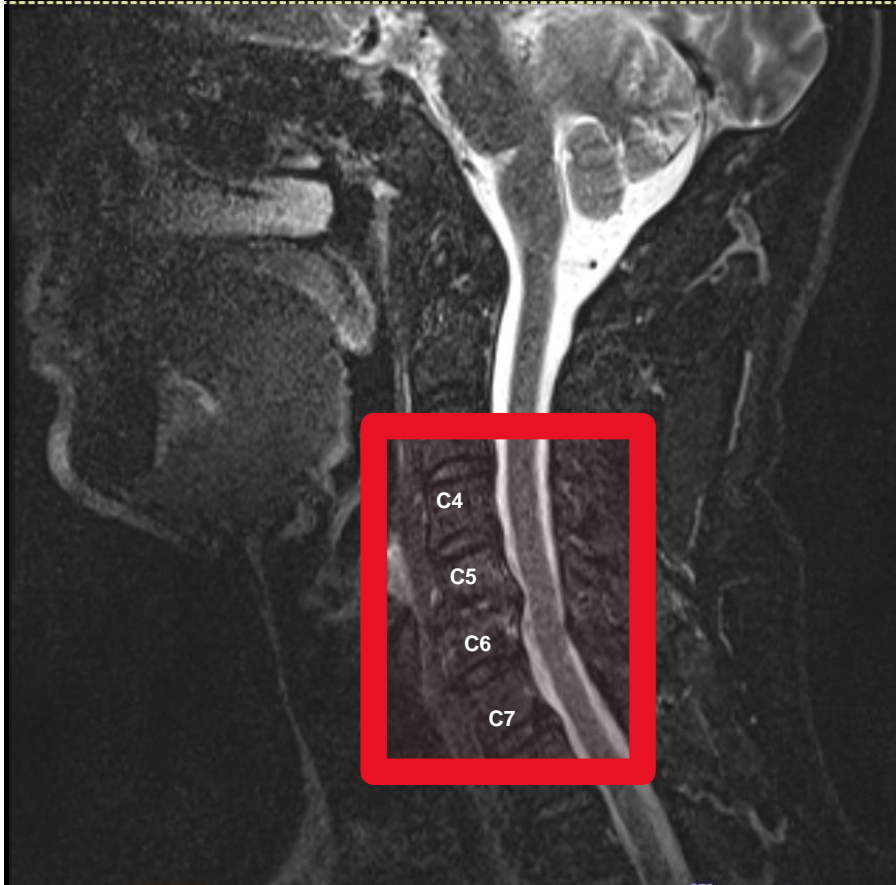
# Moving on to Spine Pathology

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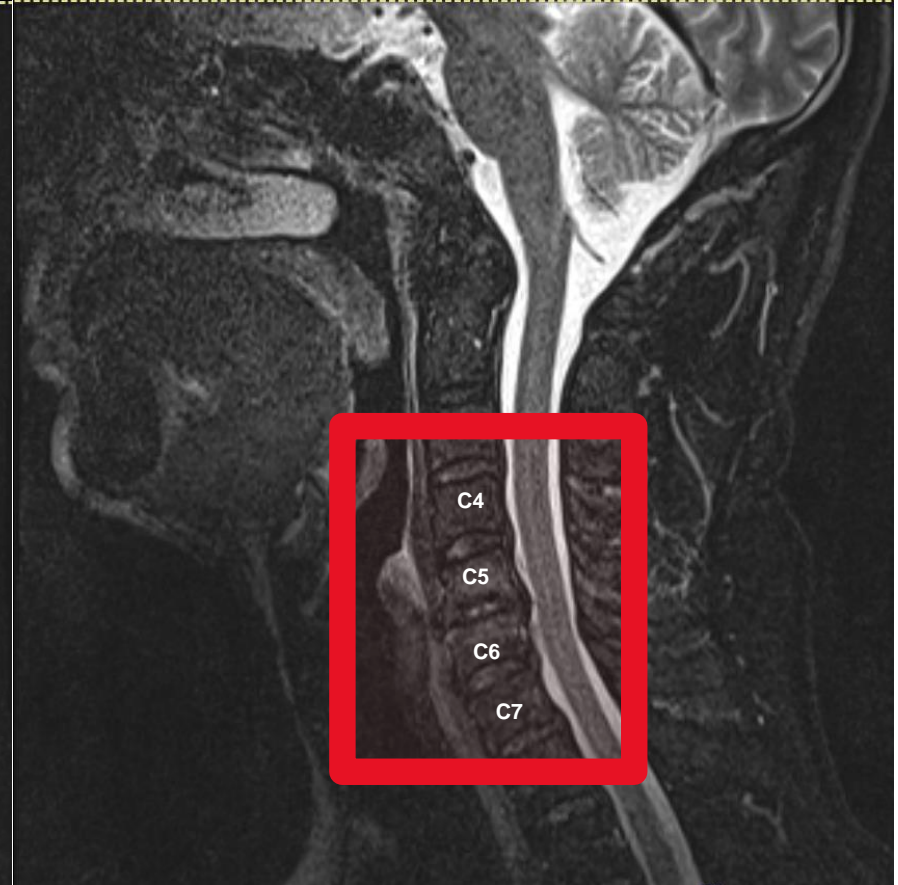




# F/U Cervical Spine MRI



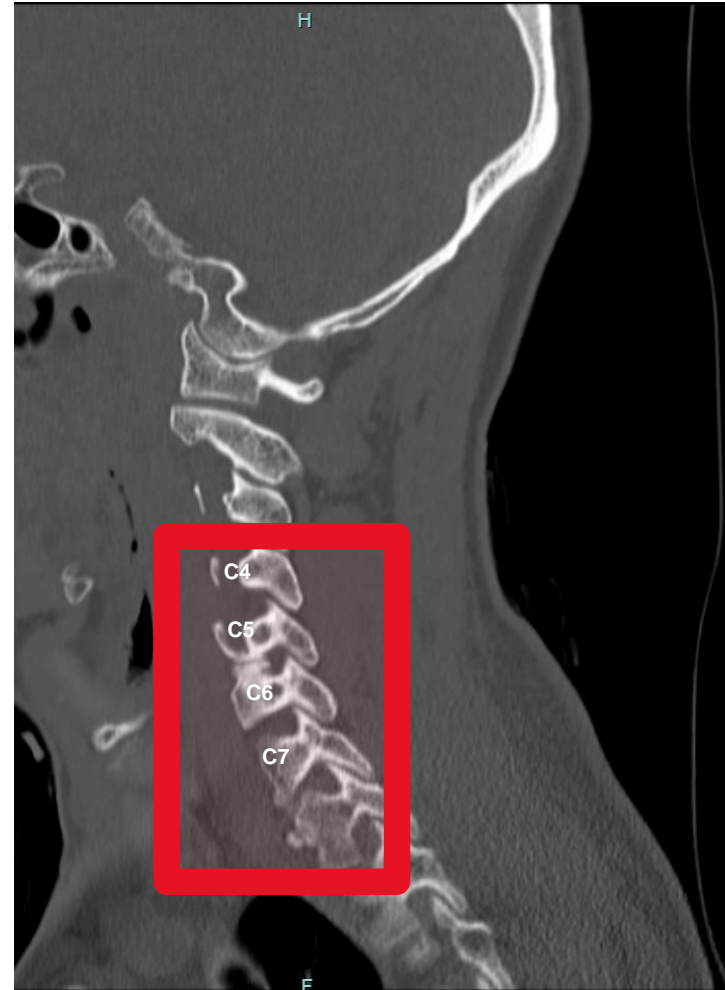
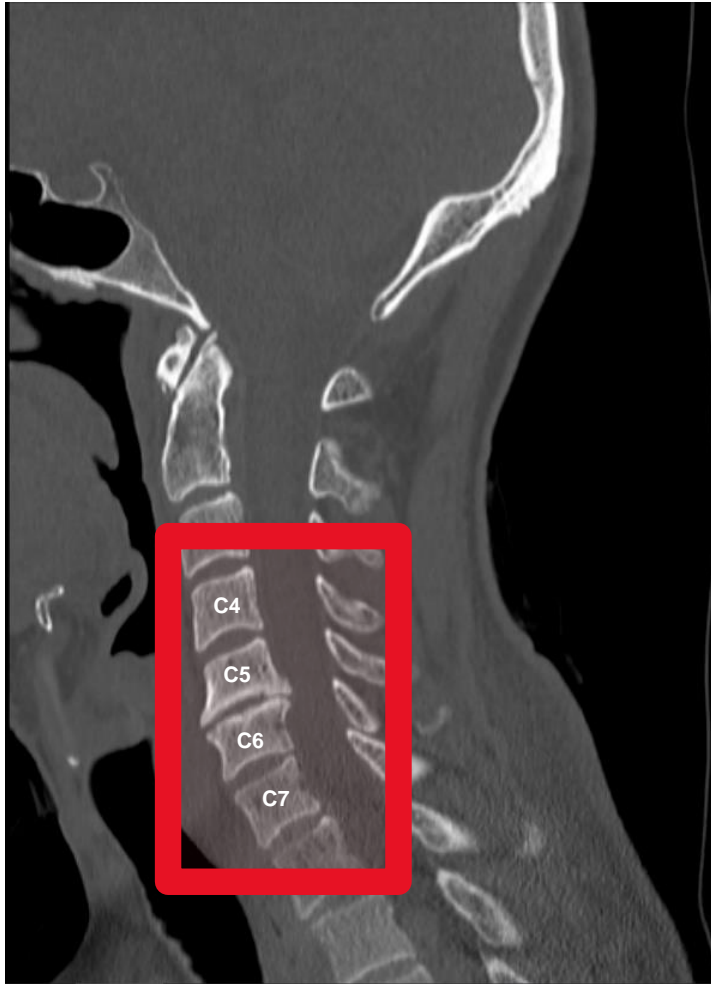
Sagittal MRI Cspine 18-Nov-2022



Sagittal MRI Cspine 29-Mar--2023



# Cervical Spine CT 29 Mar 2023





# Known Risks

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- Increased Risk of Disk Herniation in Astronauts

Risk of Herniated Nucleus Pulposus Among U.S. Astronauts

SMITH L. JOHNSTON, MARK R. CAMPBELL, RICK SCHEURING,  
AND ALAN H. FEIVESON

*Aviation, Space, and Environmental Medicine • Vol. 81, No. 6 • June 2010*

- Astronauts 4.3X more likely to have HNP
- Cervical Spine HNP was 41% of all HNPs



# Unknowns

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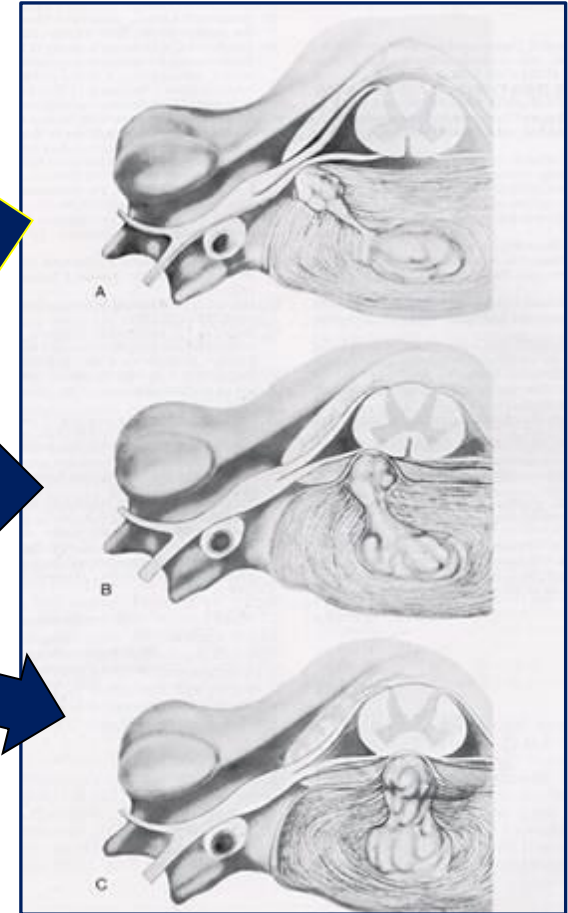
- What biochemical changes occur within the disk?
- What does traction do to the disk long term?
- Unknown Unknowns...



# Cervical Disk Herniation

Cause majority of acute radiculopathies

- Intraforaminal: most common, radicular sx in dermatomal distribution
- Posterolateral: mostly motor symptoms (weakness and atrophy)
- Midline: may cause myelopathy and the next nerve root





# Natural History

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- 70-80% of radiculopathy resolves
  - First 3 months critical
- Concern for permanent weakness after 6 months
  - Monitoring remotely difficult
- Ideal surgical window between 3 and 6 months for weakness
  - Less if profound weakness or progression





# Precedent

- Surgical Intervention
  - ACDF
  - Foraminotomy



**JNS** SPINE

HISTORICAL VIGNETTE

J Neurosurg Spine 31:87-92, 2019

**Astronaut Michael Collins, Apollo 8, and the anterior cervical fusion that changed the history of human spaceflight**

Richard Menger, MD, MPA,<sup>1</sup> Michael Wolf, MD, MS,<sup>2,3</sup> Jai Deep Thakur, MD,<sup>1</sup> Anil Nanda, MD, MPH,<sup>1</sup> and Anthony Martino, MD<sup>4</sup>



# Disposition

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- Recertify or Not for Long Duration Spaceflight?



# Conclusion

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- Cervical Spine architecture appears to be vulnerable to anatomic changes that occur in microgravity
  - Cervical versus Lumbar risk
- Expanded long duration flights
  - NASA – Mars
  - Outside organizations
- Flights longer than 3-6 months and symptoms don't improve
  - Patient Risk/Mission Risk



# Discussion: Risks & Mitigation

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- Here's the aeromedical experts and consults case for *recommending recertification* for long-duration spaceflight:
  - Lessons Learned during 64S/65S – Proven ability for on-orbit diagnosis, medical treatment, rehab, exercise modification, inflight PT, eg cervical traction, manual therapy
  - Asymptomatic last 5 months of 1-year mission
  - Asymptomatic during/after 30-Mar-22 Soyuz Landing
  - Asymptomatic during postflight rehab to Present
  - Very Low likelihood of serious future symptoms (myelitis/cord compression) per consultants
  - Known distribution of affected cervical foramen / EVA?
  - On-orbit Meds/Imaging: Steroids, Ultrasound, Pain meds, Gabapentin?
  - If becomes symptomatic pre-flight, treatment could be single-level cervical fusion with high rate of success
  - Precedent Case(s): Several lumbar HNP and one known cervical HNP on ISS



# Closing Comments

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- In the future, All Astronauts now receive preflight Cervical and Lumbar MRI per new MedB Standard



# Case Presentation- Summary

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- A healthy 55-year-old with *known* cervical degenerative disk disease developed an acute left sided C7 cervical radiculopathy four months into his long duration space flight...
  - What factors would you consider in whether to allow him to return to space considering his orthopedic history?
    - He experienced symptoms in a state of permanent traction
    - He has known multilevel DDD, ie cervical neural foramen narrowing increases risk over unaffected individual
    - There is limited capability for emergent return
    - Limited on-orbit imaging capability vs. ground, limited on-orbit medical treatment capability
    - Confounding DCS symptoms w/neurological symptoms related to radiculopathy
    - Does radiculopathy recurrence risk increase or decrease with time?
    - Does he have increased risk for stenosis or myelopathy?



# Acknowledgements

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- Dr. Ashot Sargsyan, Aaron Everett
- BME's
- LSAH
- ASCRs
- CB office



# Thank you







# Specific Strength Assessments

~~19 Sept-2021~~

Exercise	Weight	Unaffected Arm # Reps to failure	Affected Arm # Reps to failure	Hand N/T (Y/N?)	Pain (location and severity- 0-10)	Unaffected *Tester Opinion of 1-5 Strength*	Affected *Tester Opinion of 1-5 Strength*
C7- Triceps Extension	22	16	9	N	0		
C7- Triceps Extension	20	16	12	N	0		
C7- Triceps Extension	20	16	10	N	0		
C7- Triceps Extension	17	16	13	N	0		
T1- Finger Abduction*							

05-Sept-2021

Exercise	Weight (remains unchanged)	Unaffected Arm # Reps to failure	Affected Arm # Reps to failure	Hand N/T (Y/N?)	Pain (location and severity- 0-10)	Unaffected *Tester Opinion of 1-5 Strength*	Affected *Tester Opinion of 1-5 Strength*
C5- Biceps Curl	27	21	22	not noticed	none		
C6- Wrist Extension	20	17	16	not noticed	none		
C7- Triceps Extension	25	23	0	not noticed	none		
C8- Thumb Extension*						3	3
T1- Finger Abduction*						3	3

12-Sept-2021

Exercise	Weight (remains unchanged)	Unaffected Arm # Reps to failure	Affected Arm # Reps to failure	Hand N/T (Y/N?)	Pain (location and severity- 0-10)	Unaffected *Tester Opinion of 1-5 Strength*	Affected *Tester Opinion of 1-5 Strength*
C5- Biceps Curl	22	11	6	not noticed	none		
C6- Wrist Extension	22	11	4	not noticed	none		
C7- Triceps Extension	25	11	10	not noticed	none		
C8- Thumb Extension*	10	11	11			3	3
T1- Finger Abduction*						3	3



# Dynamic Cervical Spine Exercises

~~20~~ Sept-2021

Session Date: _____	Before:		During:		After:	
	Pain Location and Severity (0-10)	Numbness/Tingling Location and Severity (0-10)	Pain Location and Severity (0-10)	Numbness/Tingling Location and Severity (0-10)	Pain Location and Severity (0-10)	Numbness/Tingling Location and Severity (0-10)
Exercise 1 (Seated cervical retraction with rotation- 3x10)	0	2, right 1st and 2nd digits	2, at limits of rotation, in neck. Felt no worse than normal stretching	Same as before	1 neck felt a bit sore	1 same locations, slightly reduced if any change at all
Exercise 2 (Seated cervical retraction w/ no resistance- 3x10)	0	1 same	1, sensation of tightness across right scapula	1 same	1 warm sensation on neck, nonpainful	1 same
Exercise 3 (Angel Wings w/resistance 3x10)	0	1 same	1 right back of head felt warm	1 same	1 neck felt a bit stiff	1 same

*“I feel about 80% improved overall, in terms of symptom discomfort, provocative movement, and strength. The arm weakness and fingertip tingling is there, but minimal. I’m almost forgetting about it during the workday.”*



Search



Return to Activity

Real Time

Mon 184 Tue 185 Wed 186 Thu 187 Fri 188 Sat 189 Sun 190 Mon 191 Tue 192



Day Night	[Black bars]							[Black bars]								
Daily Orbit	7		8		9		10		11		12		13			
ISS ATTITUDE	+XVV +ZLV TEA															
Houston	01	02	03	04	05	06	07	08	09	10	11	01	02	03	04	
GMT	06	07	08	09	10	11	12	13	14	15	16	06	07	08	09	
Moscow	09	10	11	12	13	14	15	16	17	18	19	09	10	11	12	
TDRS ALL	[Colorful bars]															
FE-3 Frank	POSTSLEEP		EXERCISE-ARED				EXERCISE-CEVTS		MIDDAY-MEAL		HM PFC					
FE-14 Steve	POSTSLEEP		EXERCISE-ARED		EXERCISE-CEVTS		MIDDAY-MEAL									
FE-15 Woody	POSTSLEEP						MIDDAY-MEAL						EXERCISE-ARED			
FE-16 Sultan	POSTSLEEP						EXERCISE-CEVTS		EXERCISE-ARED		MIDDAY-MEAL					
FE-17 Andrey	POSTSLEEP		BF W				MIDDAY-MEAL		COX-MNT							
CREW	HANDS OFF FSL															
	<div style="display: flex; justify-content: space-between;"> <div style="width: 45%;"> <p>Of</p> </div> <div style="width: 50%;"> <p>*****</p> <p>*****</p> <p>*****</p> <p>*****</p> <p>*****</p> <p>*****</p> </div> </div>															
SPECIALIST	MCC-H FCT H/O (1/2)															

OPTIMIS Viewer

70%



# USAF Waiver Guide

A history of HNP or surgery for it is disqualifying for FC I/IA/II/III and requires a waiver under MSD K6. All flying classes and OSD personnel require a waiver when they fall under MSD K5: “Herniation of nucleus pulposus, when symptoms and associated objective findings are of such a degree as to require repeated hospitalization, significant duty limitations, or frequent absences from duty.” MSD K5 is disqualifying for retention standards, so would also require an MEB or RILO. If surgical intervention is contemplated, note that cervical disc arthroplasties (artificial disc replacements) are not routinely aeromedically-approved for highperformance aircraft operation waiver, and may also be duty-limiting for personnel on jump status. Aviation personnel must fulfill all of the following applicable qualifying criteria for the initial waiver request: - Need to be asymptomatic or with non functionally-limiting symptoms or signs - Need to have adequate waiting period after treatment - see Table notes - Please note difference in waiting times for different categories.

**Table 1: Waiver potential for HNP treated conservatively, or surgically without fusion or disc replacement**

<b>Flying Class (FC)</b>	<b>Waiver Potential</b>	<b>Waiver Authority</b>	<b>ACS Review or Evaluation</b>
FC I/IA	No	AETC	No
FC II	Yes <sup>1,2</sup>	MAJCOM	Yes <sup>3</sup>
FC III	Yes <sup>1,2</sup>	MAJCOM	No
ATC, GBO, SWA	Yes <sup>1</sup>	MAJCOM	No

1. Minimum observation period post-treatment: 6 months if on jump status, otherwise 3 months

2. **Multi-level cervical spine surgery waivers restricted to non high-performance aircraft**

3. For cases with over 4 years stability, ACS review is not required, and is at the discretion of the waiver authority



# USAF Waiver Guide

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AIMWTS search in Mar 2019 revealed 838 members with a diagnosis of HNP and/or spinal fusion since Jan 2014. There were 97 cases resulting in disqualification.

Breakdown of the cases demonstrated:

13 FC I/IA cases (8 disqualified),  
442 FC II cases (30 disqualified),  
18 RPA pilot cases (1 disqualified),  
344 FC III cases (50 disqualified),  
19 ATC/GBC cases (8 disqualified),  
and 2 MOD cases (0 disqualified).



# US Navy Waiver Guide

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## Designated Personnel:

In designated personnel who are currently asymptomatic, the condition is CD but is usually considered for a waiver. Students already under instruction may also be considered for a waiver. All Dispositions and waiver requests must be based upon the following criteria, defined by region: Cervical: 1. Without radicular symptoms: Clinical presentation is neck pain, occasional spasms, and/or occasional crepitus. Radiographs show narrowing, osteophytes, or are normal. Treatment is symptomatic with NSAIDs, analgesics and cervical traction. OMT/Manual medicine by an experienced physician may also be helpful. Condition is typically seen in the 4th decade of life. Aeromedical disposition is Considered Disqualifying, Waiver Recommended (CD, WR).

Notes: An MRI diagnosis of herniated disc or bulging disc at any level of the spine, in the absence of clinical findings, is meaningless. Twenty to thirty percent of ASYMPTOMATIC people have herniated disks by MRI.



# US Navy Waiver Guide, *cont'd...*

## 13.4 INTERVERTEBRAL DISC DISEASE

Last Revised: April 16 Last Reviewed: April 16

	Applicant	Class I			Class II	Class III	Class IV
		SG 1	SG 2	SG 3			
<b>CD</b>	Yes	Yes	Yes	Yes	Yes	Yes	
<b>NCD</b>	+/-	+/-	+/-	+/-	+/-	+/-	
<b>WR</b>	+/-	+/-	+/-	+/-	+/-	+/-	
<b>WNR</b>	+/-	+/-	+/-	+/-	+/-	+/-	
<b>LBFS</b>	N/A	No	No	No	No	No	
<b>EXCEPTIONS</b>	In those who have not undergone discectomy and do not have radicular symptoms, the condition is NCD. Waivers for multi-level discectomy are not likely, but may be considered on a case-by-case basis.						
<b>LIMDU/PEB</b>	If LIMDU/PEB has been held, Grounding PE and AMS should be submitted when board written. Results of this board must be included in waiver package. Member not eligible for waiver until returned to Full Duty by Board.						

<b>Key</b>	
<b>+/-</b>	Depends upon whether listed requirements met, waiver may or may not be recommended (“Case-by-Case” basis)



# US Army Waiver Guide

**INTERVERTEBRAL DISC/DQNCERNS:** Intervertebral Disc Disease (herniated nucleus pulposus, HNP) at any spinal level is of concern in an aviation environment due to its potential impact on mission availability, functional limitation, task performance, and treatment side effects. Further of concern is the individual's increased risk in both short-term health status and in long-term progression/extent from G-Forces, ejections, hard-landings, prolonged sitting, frequent awkward postures, wear of heavy equipment and egress operations.

**Initial Class I Applicants:** History of HNP or any spinal condition producing radiographic, with or without surgery is disqualifying. Exception to policy, although not normally recommended, may be considered on a case-by-case basis with information below for remote histories with excellent recovery.

**Rated and Non-Rated Aircrew, Including all Applicants:** Waivers are favorably considered for cases, whether treated conservatively or surgically, with resolution of symptoms, return to normal duties, no residual motor-sensory-reflex deficits, no instability of posterior elements, no Permanent 3 spinal profiles and no requirement for limiting treatments or Class IV medications (with or without corrective surgery and with or without current symptomatology). Aircrew members with histories of cervical HNP and/or history of spinal fusion is disqualifying for all classes, both Initial and Rated.

will normally be restricted from aircraft requiring ejection seat capacity (which involves no current Army aircraft).





# FAA: Aerospace Medical Dispositions Item 43. Spine and other Musculoskeletal - Spine, other musculoskeletal

## Common Conditions and Course of Action

Disease/Condition	Class	Evaluation Data	Disposition
Active disease of bones and joints If due to a specific condition - see that page If due to arthritis – see arthritis page	All	Submit a current status report to include functional status (degree of impairment as measured by strength, range of motion, pain), medications with side effects and all pertinent medical reports	Requires FAA Decision
Ankylosis, curvature, or other marked deformity of the spinal column sufficient to interfere with the performance of airman duties	All	Submit a current status report to include functional status (degree of impairment as measured by strength, range of motion, pain), medications with side effects and all pertinent medical reports	Requires FAA Decision
Intervertebral Disc Surgery	All	See Footnote <sup>14</sup>	See Footnote <sup>14</sup>
Musculoskeletal effects of: Muscular Dystrophy or Myopathies	All	Submit a current status report to include functional status (degree of impairment as measured by strength, range of motion, pain), medications with side effects and all pertinent medical reports	Requires FAA Decision
Musculoskeletal effects of Cerebral Palsy or Myasthenia Gravis	All	See: <a href="#">Cerebral Palsy Disposition Table</a> See: <a href="#">Myasthenia Gravis Disposition Table</a>	Requires FAA Decision
Other disturbances of musculoskeletal function, acquired or congenital, sufficient to interfere with the performance of airman duties or likely to progress to that degree	All	Submit a current status report to include functional status (degree of impairment as measured by strength, range of motion, pain), medications with side effects and all pertinent medical reports	Requires FAA Decision
Symptomatic herniation of intervertebral disc	All	Submit a current status report to include functional status (degree of impairment as measured by strength, range of motion, pain), medications with side effects and all pertinent medical reports	Requires FAA Decision



# FAA: Aerospace Medical Dispositions

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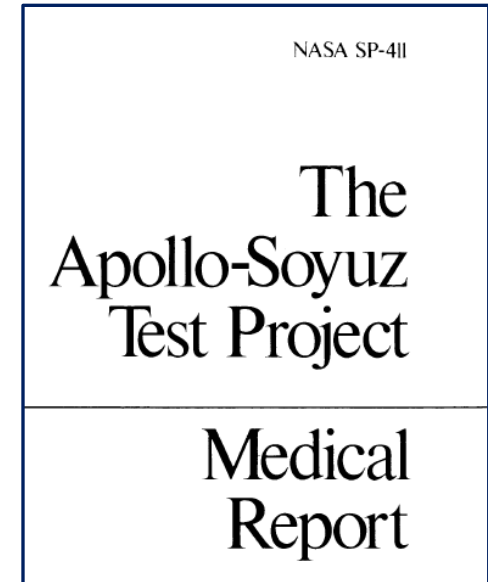
- A history of intervertebral disc surgery is **not disqualifying**. If the applicant is asymptomatic, has completely recovered from surgery, is taking no medication, and has suffered no neurological deficit, the Examiner should confirm these facts in a brief statement in [Item 60](#). The Examiner may then issue any class of medical certificate, providing that the individual meets all the medical standards for that class.

Source: [https://www.faa.gov/ame\\_guide/app\\_process/exam\\_tech/item43/amd/spine](https://www.faa.gov/ame_guide/app_process/exam_tech/item43/amd/spine)



# Background

- Spinal Elongation up to 6 cm
  - Initial period before day 6
    - Loss of lordosis/kyphosis
  - Day 6 to 9 up to 6 cm
    - Disk Expansion
- Decreased muscle mass



J Musculoskel Neuron Interact 2000; 1(2):157-160

Original Article



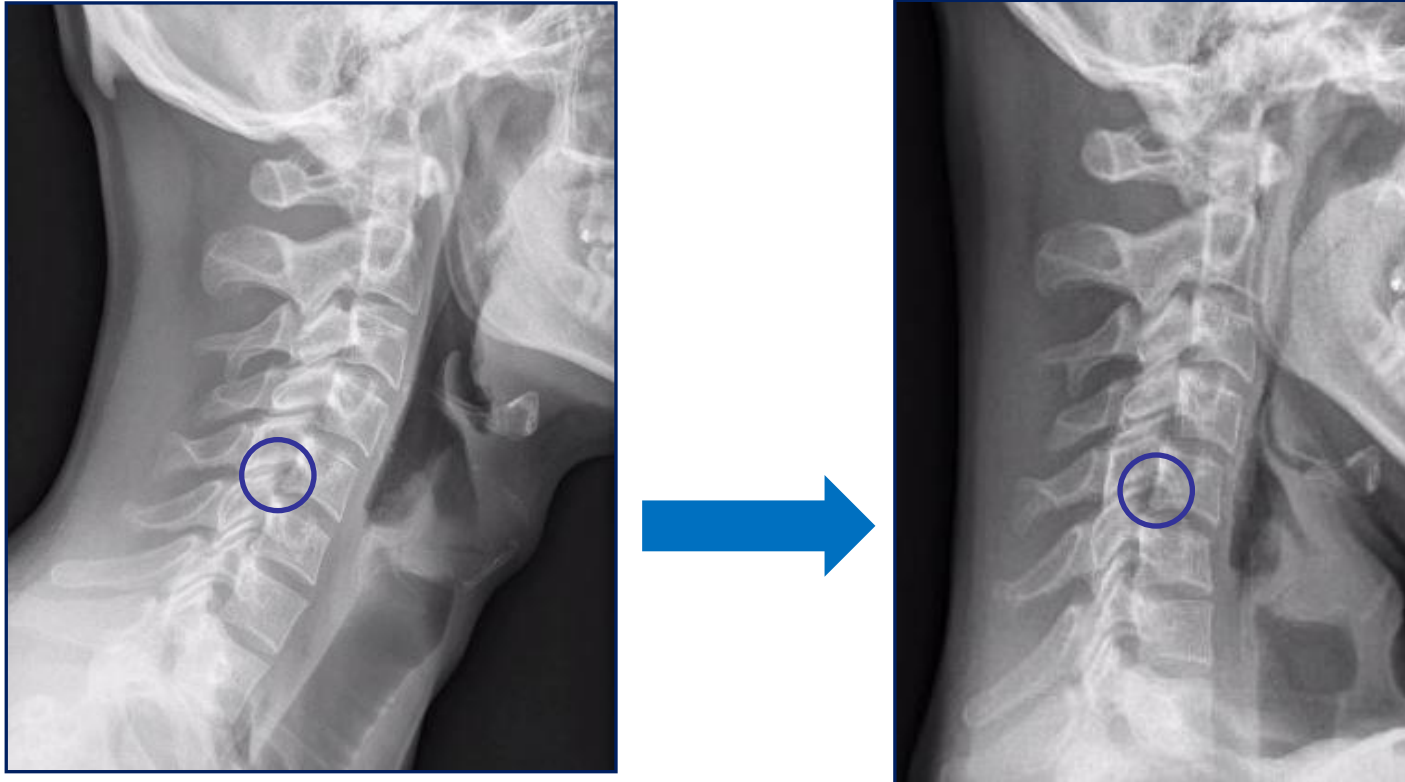
## Bone mineral and lean tissue loss after long duration space flight

A. LeBlanc<sup>1</sup>, V. Schneider<sup>2</sup>, L. Shackelford<sup>2</sup>, S. West<sup>1</sup>, V. Oganov<sup>3</sup>, A. Bakulin<sup>3</sup>, L. Voronin<sup>3</sup>

<sup>1</sup>Baylor College of Medicine, <sup>2</sup>Johnson Space Center, Houston, Texas, USA, <sup>3</sup>Institute of Biomedical Problems, Moscow, Russia



# Loss of Lordosis



- Decreased Lordosis Increased Foraminal Height



# Expansion

- Disk Expansion
  - 10% increased volume
  - Hyperhydration
  - ? Increased risk for herniation



## Lumbar Disc Volume Measured by MRI: Effects of Bed Rest, Horizontal Exercise, and Vertical Loading

WILLIAM C. HUTTON, JOHN A. MALKO, AND  
WILLIAM A. FAJMAN

*Aviation, Space, and Environmental Medicine* • Vol. 74, No. 1 • January 2003



# Biomechanical Changes

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- MRI pre and post flight
- Decreased water content
- % muscle loss in L4-S1 multifidus correlated with HNP

The Spine Journal 22 (2022) 197–206

Clinical Study

Biomechanical changes in the lumbar spine following spaceflight and factors associated with postspaceflight disc herniation

Jeannie F. Bailey, PhD<sup>a,\*</sup>, Priya Nyayapati, BS<sup>a</sup>, Gabriel T.A. Johnson<sup>a</sup>, Lucas Dzieszinski, BS<sup>a</sup>, Aaron W. Scheffler, PhD<sup>b</sup>, Rebecca Crawford, PhD<sup>c</sup>, Richard Scheuring, DO<sup>d</sup>, Conor W. O'Neill, MD<sup>a</sup>, Douglas Chang, MD<sup>e</sup>, Alan R. Hargens, PhD<sup>e</sup>, Jeffrey C. Lotz, PhD<sup>a</sup>



# Background – Known Changes

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- Changes in Disk Height
  - Initial Increase
  - Followed by Decrease
  - Overall cervical height decreased
  - Limited by inexperienced Ultrasound capture on ISS

**Preflight, In-Flight, and Postflight Imaging of the Cervical and Lumbar Spine in Astronauts**

Michael F. Harrison; Kathleen M. Garcia; Ashot E. Sargsyan; Douglas Ebert; Roy F. Riascos-Castaneda; Scott A. Dulchavsky

AEROSPACE MEDICINE AND HUMAN PERFORMANCE Vol. 89, No. 1 January 2018



# Known Risks

- Space Adaptation Back Pain
  - 52% Back Pain
  - Fetal Positioning, exercise, spinal loading treatment

## Space Adaptation Back Pain: A Retrospective Study

ERIC L. KERSTMAN, RICHARD A. SCHEURING,  
MATT G. BARNES, TYSON B. DEKORSE, AND LYNN G. SAILE

*Aviation, Space, and Environmental Medicine* • Vol. 83, No. 1 • January 2012

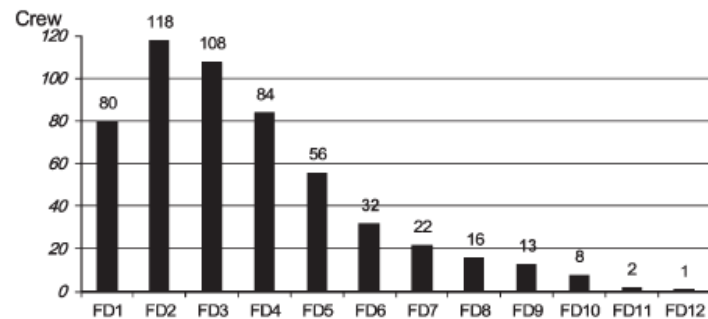


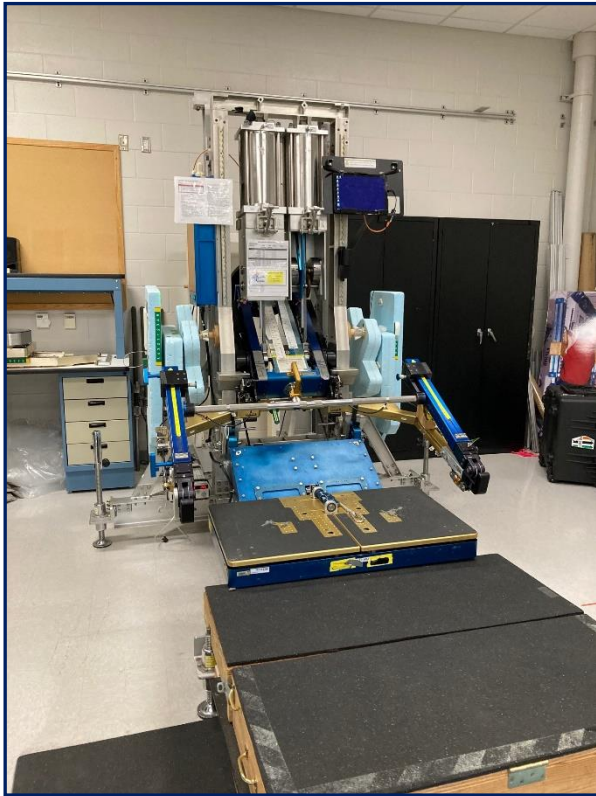
Fig. 1. Distribution of flight days that SABP was reported.





# ARED/Treadmill

- Load Lumbar Spine but not Cervical

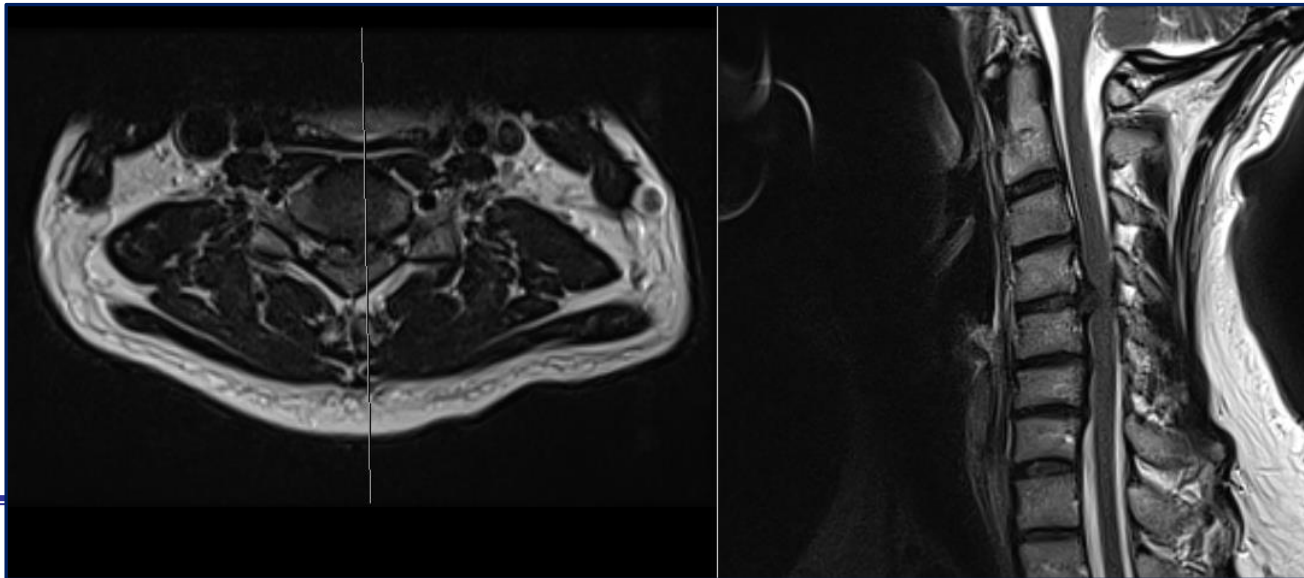




# Myelopathy

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- Gait Disturbances...
- Changes in Fine motor skills
- Numbness
- Pilot Healthcare Avoidance

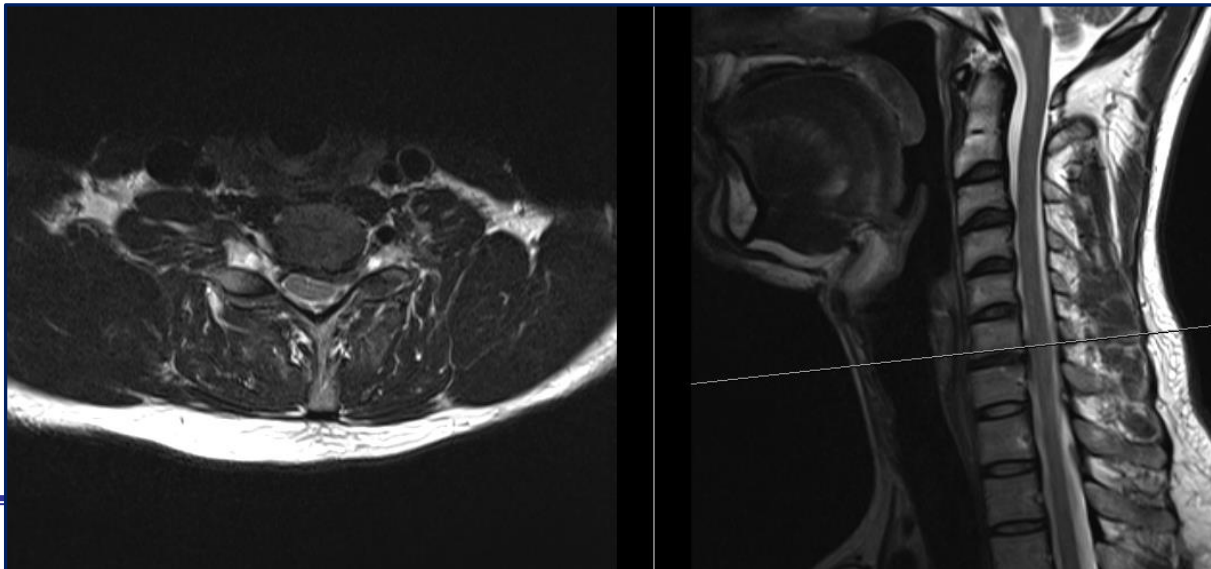




# Radiculopathy

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- How can we monitor for progress?
  - ARED/strength testing
  - Ultrasound appearance of muscle
  - Telemedicine





# Natural History

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- Recurrence of radiculopathy up to 30%
  - Clearance for long duration flight
- How can we limit problems
  - Strengthening programs





# Unique Concerns

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- Foraminal Height increased?
  - Disk Herniation more common
- Where is the disk more likely to herniate?
- How do we assess for myelopathy?
- How can we assess neurologic function?
- What happens at landing?

