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Description of 103 Cases of Hypobaric Sickness from NASA-sponsored Research (1982–1999)

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Contents

Table

Acronyms and Nomenclature

AGE	arterial gas embolism
ATA	atmosphere pressure absolute
BMI	body mass index
CM	cutis marmorata
CNS	central nervous system
DCIEM	Defence and Civil Institute of Environmental Medicine
DCS	decompression sickness
ΔP	pressure difference
DT	Doppler technician
EMU	extravehicular mobility unit (spacesuit)
ETA	environmental test article
EVA	extravehicular activity (space walk)
FGHL	p. 61
fsw	feet seawater
GLO	ground level oxygen
HBO	hyperbaric oxygen
ID	identification
JSC	Johnson Space Center
k	number of gas species in tissue
kPa	kilopascal
lbf	pound force
MO	Medical Officer
MRI	magnetic resonance imaging
n	sample size
N	Newtons of force
N_2	nitrogen
NBL	Neutral Buoyancy Laboratory
O_2	oxygen
PB	prebreathe

PFO	patent foramen ovale
PI	Principal Investigator
PRP	Prebreathe Reduction Protocol
psia	pounds per square inch absolute
PTC	Physiological Training Chamber
TT V	Treatment Table V
TT VI	Treatment Table VI
USAF	United States Air Force
USN	United States Navy
VGE	venous gas emboli

Abstract
One hundred and three cases of hypobaric decompression sickness (DCS) are documented, with 6 of these classified as Type II DCS. The presence and grade of venous gas emboli (VGE) are part of the case descriptions. Cases were diagnosed from 731 exposures in 5 different altitude chambers from 4 different laboratories between the years 1982 and 1999. Research was funded by NASA to develop operational prebreathe (PB) procedures that would permit safe extravehicular activity from the Space Shuttle and the International Space Station using an extravehicular mobility unit (spacesuit) operated at 4.3 psia. Both of these vehicles operate at 14.7 psia with an "air" atmosphere, so a PB procedure is required to reduce nitrogen partial pressure in the tissues to an acceptable level prior to depressurization to 4.3 psia. Thirty-two additional descriptions are also included of symptoms that were not diagnosed as DCS as well as of VGE information. The information for each case resides in logbooks from 32 different tests. Additional information is stored in the NASA Decompression Sickness Database and the Prebreathe Reduction Protocol Database, each of which is maintained by the Environmental Physiology Laboratory at the Johnson Space Center. Both sources were reviewed to provide the narrative that follows.

Purpose
In this report we provide, in one location, information about the hypobaric decompression sickness (DCS) observed in some of the NASA-sponsored research from 1982 to 1999. We also are including a sample of descriptions of the symptoms that were not diagnosed as DCS. We obtained this from a January to February 2003 review of many logbooks and 2 electronic databases at the Johnson Space Center (JSC). Our goal is to faithfully reproduce the information recorded during the test, information obtained during debriefing as documented by the Principal Investigator (PI), any additional information provided by the Medical Officer (MO), and information supplemented from both the NASA Hypobaric Decompression Sickness Database and the Prebreathe Reduction Protocol (PRP) Database.[1] Case descriptions of DCS serve as the basis by which we define acceptable risk of DCS during extravehicular activity (EVA), to train flight surgeons to recognize and treat hypobaric DCS, and to better understand the false positive and false negative rate of DCS in our research. This report does not contain case descriptions of DCS from the tests conducted for NASA at Brooks Air Force Base, San Antonio, Texas, over the same time period. The 15 cases of Type I DCS during 219 exposures of Doppler technicians (DTs) at JSC, which came from 8 DTs (7 males and 1 female), are also not included in this report. Neither are any cases included from the DTs at 3 other laboratories.

Decompression Sickness as a Problem
The human body tolerates limited changes in ambient pressure without suffering mechanical damage because: (a) tissues are essentially incompressible fluid, (b) all air spaces within the body communicate with ambient pressure, and (c) tissues can accommodate an increased quantity of dissolved inert gas without damage; the amount depends on the solubility, temperature, and partial pressure of inert gas in the tissue. However, when divers return from a hyperbaric environment or aviators and astronauts travel to a hypobaric environment, the potential exists for gas dissolved in fluid to come out of solution to form gas spaces that can displace or otherwise damage tissues. Displacement of tissue by trapped gas spaces can cause a wide range of signs and symptoms, which are collectively called DCS. Gas evolution in the body is the primary

insult, but the activation of a host of biochemical processes in response to the evolved gas undoubtedly also contributes to the signs and symptoms of DCS.

Two strategies, excluding the fascinating possibility of liquid breathing, are available to prevent DCS. The first strategy is to keep a desired ambient gas pressure on the body constant by engineering a mechanical structure around the body. The use of one-atmosphere spacesuits and diver suits, counter-pressure suits, submarines, and pressurized aircraft cockpits are approaches that maximize human safety but are very costly in terms of engineering, complexity, materials, and inaccessibility to the environment. The second strategy is to expose the body to the hyperbaric or hypobaric environment while reducing ambient pressure at a rate that avoids or limits bubble formation in the tissues. This approach takes advantage of tissue incompressibility, tissue accommodation to a quantity of dissolved inert gas, and accessibility to the environment, and is also less costly in engineering and materials – although it is not necessarily as safe as the first approach. Indeed, this approach requires a theoretical or an empirical understanding of DCS from which to develop decompression strategies.

The second strategy has been successfully exploited by NASA since the beginning of the U.S. space program. With this strategy in place, astronauts and technicians test different configurations of the extravehicular mobility unit (EMU) at 4.3 pounds per square inch absolute (psia) while the hypobaric chamber is near vacuum. Astronauts train for various EVA tasks while they are either at 4.3 psia in altitude chambers or at 4.3 pounds per square inch delta while in the Neutral Buoyancy Laboratory (NBL). Although astronauts perform EVAs in microgravity, they are also aviators who fly at reduced ambient pressure – and fly after diving at the NBL. Moreover, there are situations where astronauts are exposed to hypobaric conditions in altitude chambers after first diving at the NBL. Also, NASA employs pilots who are not astronauts but who perform high-altitude flying. Finally, support divers at the NBL may also fly after diving, and test subjects are exposed to hypobaric environments as part of the NASA research programs that are conducted to understand the risk of DCS. In all of these cases, risk mitigation strategies are necessary to prevent DCS.

Fundamental Cause of Decompression Sickness

A fundamental axiom about DCS is that a transient gas supersaturation, also known as overpressure or pressure difference (ΔP), exists in a tissue region. The sum of all gas partial pressures in that region is greater than the ambient pressure opposing the release of the gas. Expressed as an equation, supersaturation exists when ΔP is positive:

$$\Delta P = \sum_{i=1}^{k} P_1 - P2$$

where P_1 is the partial pressure of the i^{th} gas of "k" species in the tissue and P2 is the ambient pressure after decompression. The potential for bubble nucleation and rate of bubble growth are related to the magnitude of the supersaturation.

Although gas supersaturation in the tissue is not in itself harmful, it is nevertheless an unstable condition between the tissue and the surrounding environment. The difference in tissue gas

partial pressure and ambient pressure can be resolved with a phase transition, and some of the excess mass (moles) of gas in the form of bubbles may be accommodated by the tissue, causing no symptoms. Whenever a gas space is formed due to the partial or complete desaturation of a supersaturated tissue, there is a possibility of contracting DCS.

A necessary but insufficient condition in the mechanical view of DCS is the formation of a gas phase in the tissue. The assumption that pain results from the deformation of tissue past a critical point due to evolved gas may be too simplistic to account for symptoms other than pain-only Type I DCS, but it does account for the primary cause of DCS. The determining factor of DCS may not be the presence or even absolute volume of evolved gas in the tissue, but rather the pressure difference (deformation pressure) between the gas space and the tissue.

Prevention of Hypobaric Decompression Sickness

Two strategies to prevent hypobaric DCS are either to use a high-pressure spacesuit or to reduce the nitrogen (N_2) partial pressure in the tissues prior to a depressurization to a low-pressure spacesuit. The latter strategy is the one NASA has chosen. Prebreathing 100% oxygen (O_2) from minutes to hours while resting is a proven and practical approach because of its cost effectiveness, as we alluded to. Other approaches to achieve the same goal of reducing the N_2 partial pressure in the tissues are to "stage" decompression at 10.2 psia while breathing 26.5% O_2, or to exercise during PB at 14.7 psia to accelerate denitrogenation. In this report, we have described resting PB, staged decompression, and exercise during PB as the denitrogenation options.

Classification of Decompression Sickness

DCS symptom(s) are classified into Type I and Type II DCS at JSC, so it is necessary that we define these categories since this terminology is used in our records. Currently, the definitions for all evolved gas disorders reside in the Decompression Sickness Procedures and Guidelines (JPG 1800.3A) and JSC Policy Directive JPD 1800.2A.

Mild decompression sickness (DCS Type I): Symptoms of mild DCS (DCS Type I) involve joint pain, peripheral nervous system, or simple skin bends.

In Bends 1, a 4-point scale that is used primarily to categorize the intensity and performance impact of pain-only Type I DCS was developed by Waligora[5] as:

- DCS Grade 1 – occasional, intermittent joint pain
- DCS Grade 2 – steady but tolerable joint pain
- DCS Grade 3 – severe and steady joint pain; not incapacitating
- DCS Grade 4 – severe joint pain with incapacitation of subject

After Bends 1, the traditional scale was modified when Waligora[5] developed a 7-point symptom scale for Bends 2–11. A pain scale above 3 was never achieved due to the test termination criteria in place for all testing at JSC. The complete scale can be found in reference 5. Definitions of the first 3 grades are:

- DCS Grade 1 – Joint awareness: Reports of awareness or fullness of joints. Subject does not experience discomfort and may not be certain that the sensation felt is other than the normal feeling arising from fatigue.
- DCS Grade 2 – Threshold of pain: Reports of discomfort, ache, or intermittent pain. The sensation does not interfere with activity. The subject may liken this feeling to a transient pain or stiffness that occurs during warm-up exercises.
- DCS Grade 3 – Pain: Reports of continuous pain rather than of ache or discomfort. Subject indicates that pain is just starting to interfere with activity. Some favoring of affected limb is reported or noticed by observers.

In Bends 11, the exposure is terminated at the diagnosis of DCS by the attending MO regardless of the degree of performance limitation or intensity of the Type I symptom(s). For Bends 11 and all subsequent NASA-sponsored tests, the test is terminated at the diagnosis of DCS, or for any persistence symptom even if DCS could not be diagnosed. The JSC case descriptions include the grade of the Type I symptom.

Serious decompression sickness (DCS Type II): Symptoms of DCS Type II involve the central nervous system (CNS), the cardiovascular system (circulatory collapse/shock), and the pulmonary system (the chokes). A more complete discussion of symptoms that have been classified as Type II can be found in reference 2. Symptoms related to unusual presentation of headache are also included under Type II DCS.

Cutis marmorata (CM)[*] : CM is a sign of DCS that appears on the skin as a mottled pattern.

Placing a sign or symptom of hypobaric DCS into Type I or Type II DCS is artificial and causes problems if a sign or symptom does not conveniently fit into one category or the other. The problem becomes acute when we attempt to categorize CM from a hypobaric exposure into Type I or Type II DCS. A categorization scheme only lends itself to quick and effective treatment strategies if it is specific. CM does not lend itself to a specific category, however.

CM, based on the best medical advice at that time, was initially categorized as Type II DCS at JSC. As a result, 1 case (ID# 149-01) was classified as Type II DCS based only on the presence of CM. Since the current definitions of DCS at JSC assign CM to a category by itself, CM is no longer deemed Type I or Type II DCS.

CM was supposedly initiated by a disturbance within the CNS, or a whole-body systemic response linked to a large volume of evolved gas. Therefore, a proper clinical response was initially to treat with a United States Navy (USN) Treatment Table V (TT V), even when no other symptoms were present. This aggressive treatment of CM resulted from an incomplete understanding of its pathophysiology, and the observation that CM may be associated with serious Type II symptoms. Thus in essence, hyperbaric treatment was provided to affect a serious symptom not yet expressed. More information about CM can be found in reference 3.

[*] Also described as skin marbling or skin mottling.

Arterial Gas Embolism (AGE): AGE is an evolved gas that produces the signs and the symptoms consistent with passage of that gas to the arterial circulation; i.e., severe neurological manifestations.

We do not have a description of a diagnosed case of AGE. There are, however, 6 descriptions in this report of what was classified as Type II DCS. AGE cannot be definitively discounted as being one of these since the rapid return to site pressure prevented the development of symptoms that could have been used to diagnose AGE. Although information about patent foramen ovale (PFO) was collected from prospective and retrospective cases to better understand the risk of AGE, the results were inconclusive. A summary of this effort is provided in Appendix B.

Classification of Venous Gas Emboli

Information about venous gas emboli (VGE) was routinely collected and evaluated at JSC to establish its statistical association with DCS symptoms. We have provided the method for collecting and grading VGE below since data about VGE are part of the DCS descriptions.

The pulmonary artery blood flow (venous blood) was insonated by a DT who was using a transcutaneous Doppler ultrasound bubble detector. VGE monitoring was performed approximately every 16 minutes for 4 minutes. The subject, while in either a supine or a seated position, was prompted to flex each limb in turn approximately 3 times to dislodge VGE from the tissue capillaries and improve VGE detection and grading. Trained observers used the audio signal from the bubble detector to assign a grade for VGE from each of the 4 limbs on the 0 to IV Spencer scale.[4] We paraphrase the definitions as originally published by Spencer:

- Grade 0 is the complete lack of bubble signals in all cardiac cycles.
- Grade I is the occasional bubble signal detected in a cardiac cycle with the majority of cardiac cycles free of bubble signals.
- Grade II is when many, but fewer than half, of the cardiac cycles contain bubble signals.
- Grade III is when most of the cardiac cycles contain bubble signals, but are not overriding the cardiac motion signals.
- Grade IV is when bubble signals are detected continuously through the cardiac cycles such that the signal overrides the amplitude of the cardiac motion and blood flow signals.

Test Termination Criteria

The test termination criteria for DCS evolved through the years. Initial tests for this were stopped at JSC when DCS was first diagnosed and it became clear that most symptoms of Type I DCS identified early in exposure would not be of sufficient intensity to stop an EVA. A decision was then made to allow the exposure to continue past the point when the subject first reported experiencing a Grade 1 or Grade 2 Type I symptom. When a subject reported experiencing a Grade 3 or higher Type I symptom or when any Type II symptom was reported, tests were terminated and the subject was removed from the altitude chamber.

In these tests, Grade 3 or higher Type I DCS was defined as exhibiting symptoms that interfered with the normal performance of test activities. A performance limitation often meant that a subject would favor an affected limb either consciously or unconsciously during the performance

of the prescribed EVA-simulation exercise. Since subjects were allowed to continue the test if they experienced Grade 1 or 2 Type I DCS, a subjective "pain intensity" scale from 1–10 was instituted. Subjects would volunteer or be asked, at hourly intervals, to gauge the intensity of a Type I symptom as the test continued. The case descriptions we have provided following include examples where pain intensity remained constant (high or low), increased in intensity, or decreased in intensity to the point that there were no symptoms by the end of the test. The pain intensity score was not rigorously applied in all cases.

Test termination criteria continue to be narrowly defined at JSC, primarily due to an increased emphasis on subject safety. For Bends 11 and all subsequent tests sponsored by NASA, the test was terminated at the diagnosis of DCS or for any persistence symptom – even if DCS could not be diagnosed. These details are provided since test termination criteria influence the confidence we have in a diagnosis of DCS. A rapid return to site pressure will maximize subject safety, but it also may prevent enough data being collected to make a confident diagnosis of DCS.

Additional Details

All JSC subjects met the minimum requirements of a modified Class III NASA Flight Physical, plus any other requirements specific to that particular test. Tests that were not performed at JSC also required that the test subject meet minimum physical standards, plus any other requirements specific to a particular test. No test was performed without the prior approval of the Institutional Review Board of a particular testing organization.

A coded identification (ID) number distinguishes subjects in this report. Since the subjects were assigned unique ID numbers sequentially, a lower ID number indicates that the subject participated in an earlier test than a subject with a higher ID number. Also, the last 2 digits of the ID number indicate participation in more than 1 test by the same subject. For example, an XX-03 indicates that this was the third exposure for that subject. No subject participated twice in the same prebreathe (PB) protocol, but a subject could participate in different PB protocols.

Inclusion of female subjects started with Bends 5. Bends 7–9c had a crossover-dependent sample statistical design. This means that each subject served as his or her own control. All other tests had an independent sample statistical design, meaning that subjects did not serve as their own controls and were a random sample that participated once to evaluate a particular PB protocol.

The exercise performed at altitude is as significant a consideration as the denitrogenation protocol. All subjects performed exercise while at the test altitude. For all tests past Bends 1, subjects were required to practice the EVA-simulation exercises in the laboratory several days prior to altitude exposure. The purpose was to familiarize them with the exercise protocol and to document symptoms caused by exercise devices. This information was used to improve the differential diagnosis of DCS on the day of altitude exposure. The exercise in Bends 2–11 was modeled after contingency EVA tasks. The exercise performed as part of the PRP, after Bends 11, was modeled on typical EVA work tasks. Both exercise protocols stressed the upper body; i.e., the hands, wrists, forearms, and shoulders. Reference 6 details the exercise protocols used in Bends 1–4 and Bends 6. Reference 7 describes exercise protocols used in the PRP tests. Bends 7 included a row machine during the second hour of a 3-hour test. Also, the shift in testing from the environmental test article (ETA) to the Physiological Training Chamber (PTC) in Bends 5

and 7–11 meant that the same exercise equipment used in earlier tests in the ETA had to be mounted slightly differently. Reference 8 discusses the unique horizontal mounting of the exercise equipment in Bends 9a. Bends 9 (9a, 9b, 9c, 9d, 9e) and 11 comprised the ARGO series.[9,10]

Subjects in Bends 9a were "adynamic" before and during the test. They performed upper body exercise while on their backs in a 6-degree head-down tilt. This non-ambulatory condition was analogous to microgravity adaptation. Subjects in Bends 9b ambulated within the PTC, moving from one exercise station to the next, as was done in Bends 8. Subjects in all subsequent ARGO tests were adynamic by virtue of resting in a chair prior to the test, and exercised from a seated position with all exercise equipment mounted at arm's reach. All subjects in the PRP testing were also adynamic and exercised from a semi-recumbent position on a cot configured with various exercise devices.[7]

We accept as the official time of a symptom the time at which a subject first communicates a symptom, not the time at which a subject recalls that symptom as first appearing. Nevertheless, all of the information about a symptom is provided in the narratives. Often debriefing notes or written case descriptions added to the logbooks after the tests were better organized and more complete. Use of a 1–10 pain scale was formally implemented after the Bends 1 test, so subjects were instructed to interpret the intensity of any symptom on this 10-point scale. Subjects were first asked to pinch themselves until the pain was intolerable. They were then to reference their symptoms on the day of the test with a 10 being the greatest intensity of that earlier pinch. The scale was not perfect, but researchers needed to score the intensity of a symptom.

Pressure in this document has units of psia. Pressure gauges in most U.S. altitude chambers, in most U.S. military aircraft, in the Space Shuttle, on the International Space Station, and even on the EMU are given in this unit. A conversion to the common metric unit of kilopascal (kPa) is through the relationship 1 psia = 6.89 kPa where 1 atmosphere pressure absolute (ATA) = 14.7 psia = 101.32 kPa. Expressing pressure in terms of feet or meters altitude is avoided.

It is unfortunate that not all case descriptions are complete. Information not presented means the information was unavailable, not that it was selectively excluded or overlooked. Indeed, we took every opportunity to reproduce the word-for-word descriptions documented in the logbooks. We did not use the word "pain" to describe a reported symptom unless "pain" was the word used by the PI. Often an awareness, a fullness, or an ache was used to describe Type I symptoms; and we used this terminology. Often the logbook entries were abbreviated conversations occurring in real time that the PI or Test Director was able to document. We therefore reconstructed these snippets of documented comments into a standard timeline format, using readable text.

Format of Case Descriptions

The format for each case description is organized into 5 sections: (1) a **Summary** of subject ID number that can be used to obtain additional information, age, gender, maximum grade of VGE detected, time to first detection of VGE, time to report the first symptom(s), and the sample size of a particular PB procedure; (2) a code from 1 to 26 of the PB **Procedure** with details concerning the PB, altitude, ascent rate, exposure duration, and exercise performed at the test altitude as shown in Appendix A; (3) a detailed **Narrative** of reported symptoms(s), additional information

about VGE associated with the narrative, intensity of pain reported on a 1–10 pain scale, altitude at which symptom(s) improved or abated, a secondary narrative in only a few cases written by someone else at the time of the event and identified with a smaller font size; and (4) the **Diagnosis** of symptom(s) and a brief summary of any posttest **Treatment**. Documentation of posttest treatment in early tests is not as clear as other information, except in the cases when hyperbaric oxygen (HBO) treatments were provided. Posttest treatment evolved from expensive medical observation for 12 hours for all cases of DCS to the release of subjects with resolved DCS and follow-up consultation the next day to 1 or 2 hours of posttest ground level oxygen (GLO) for those cases with resolved DCS to even 1 hour of GLO for all subjects and DT with just VGE during the test. The uncertainty in posttest treatment is documented.

Table I presents a summary of the 103 DCS case descriptions. This table is designed to help readers quickly find particular cases of interest, such as those cases classified as Type II DCS, those cases without VGE associated with DCS symptoms, or those cases where symptoms were localized only in the upper body. Three of the column headings need further description, however: VGE time, DCS time, and symptom site.

VGE time is elapsed time from the start of the test at altitude to first detection of VGE of any grade. The word "novge" means that VGE were not detected during the test. DCS time is elapsed time from the start of the test to when the subject *noticed* the first symptom attributed to DCS. In some cases, the first time a symptom was noticed is the same time at which the symptom was reported. These are the DCS times that appear in Table I without special marking. In some data analyses, the time the symptom was reported is critical; but in other cases, the best estimate of when a symptom was first noticed is critical. In some of the cases shown in the table, the first time a symptom was noticed was not reported until a later time – often during a formal questioning at the end of each hour of testing. These DCS times are marked with a "# "in Table I. When a subject could accurately recall the first time a symptom was noticed, that is the DCS time. Finally, in a few cases shown in the table the time when a symptom first appeared was obtained during debriefing of the subject after the test. These DCS times are marked with a "+" in Table I. In 2 cases, symptoms were not reported during the test and DCS was diagnosed following a test, but there was no accurate estimate made of when the symptom(s) first appeared. These 2 cases are marked "---" as DCS time. Finally, symptom site is designated as upper, lower, both, or other. When the column shows "upper", the site of the symptom(s) was localized in the upper body; i.e., the hand, wrist, elbow, shoulder, back, head (except for unusual headache), or arm. A "lower" designation indicates the site of the symptom(s) was in the lower body; i.e., foot, ankle, knee, hip, or leg. A "both" designation means multiple symptoms were localized in both the upper and the lower body; and "other" means the symptom(s) could not be classified as Type I "pain-only" DCS.

Table I: Summary of 103 Cases of DCS

record	subject ID	test ID	location of test	DCS type	VGE time (minutes)	DCS time (minutes)	symptom site	date of test
1	21-01	1a	JSC	I	46	44	lower	08/03/82
2	25-01	1a	JSC	I	27	49	lower	08/05/82
3	26-01	1a	JSC	I	59	75	lower	08/06/82
4	27-01	1a	JSC	I	47	76	lower	08/06/82
5	12-01	1b	JSC	I	62	77	lower	07/26/82
6	11-01	1b	JSC	I	6	28	lower	07/26/82
7	2-01	1b	JSC	I	57	64	lower	07/22/82
8	20-01	1c	JSC	I	19	76	lower	08/02/82
9	19-01	1c	JSC	I	25	78	lower	07/31/82
10	18-01	1c	JSC	I	69	104	lower	07/31/82
11	15-01	1c	JSC	I	37	166+	lower	07/30/82
12	11-02	1d	JSC	I	34	50+	lower	07/28/82
13	10-02	1d	JSC	I	62	60+	lower	07/28/82
14	37-02	2a	JSC	I	55	59	other	11/24/82
15	35-02	2a	JSC	I	116	116	lower	11/30/82
16	21-02	2a	JSC	I	105	76	lower	11/24/82
17	34-01	2a	JSC	I	77	42+	lower	11/22/82
18	5-02	2a	JSC	I	104	160	lower	11/29/82
19	32-01	2a	JSC	I	18	---	lower	11/29/82
20	38-03	2a	JSC	I	216	221	lower	11/30/82
21	35-03	2b	JSC	I	34	17	lower	12/05/82
22	34-02	2b	JSC	I	69	206#	lower	12/10/82
23	31-03	2b	JSC	I	144	180	upper	12/10/82
24	3-03	2b	JSC	I	76	175	lower	12/03/82
25	21-03	2b	JSC	I	37	160	both	12/08/82
26	18-02	2b	JSC	II	1	65	other	12/04/82
27	42-02	3a	JSC	I	34	294#	lower	05/26/83
28	47-01	3a	JSC	I	4	50#	lower	06/09/83
29	46-01	3a	JSC	I	76	120#	lower	06/07/83
30	44-02	3a	JSC	I	42	86	lower	05/26/83
31	61-03	3a	JSC	I	41	78#	lower	07/05/83
32	13-04	3a	JSC	I	88	180#	lower	06/07/83
33	63-01	3b	JSC	I	24	90#	lower	06/28/83
34	60-01	3b	JSC	I	134	300	lower	06/27/83
35	51-01	3b	JSC	I	novge	240	upper	05/18/83
36	47-02	3b	JSC	I	39	113#	lower	06/27/83
37	8-04	3b	JSC	I	113	164#	lower	07/10/83
38	27-05	3b	JSC	I	256	324#	lower	07/10/83

39	44-01	3b	JSC	I	107	221#	both	05/19/83
40	62-02	3b	JSC	I	103	105#	lower	07/10/83
41	44-03	3c	JSC	I	77	105	lower	05/27/83
42	48-03	3c	JSC	I	172	296#	lower	06/11/83
43	10-07	3c	JSC	I	221	201#	lower	05/24/83
44	60-03	3d	JSC	I	105	239	lower	07/13/83
45	42-05	3d	JSC	I	149	216#	lower	07/15/83
46	64-01	4a	JSC	I	16	24#	both	06/12/84
47	91-01	5a	JSC	I	128	165#	lower	04/11/85
48	92-01	5a	JSC	I	277	292#	upper	04/11/85
49	96-01	5a	JSC	I	39	60	lower	04/25/85
50	97-01	5a	JSC	I	91	104#	lower	05/02/85
51	109-01	6	JSC	I	98	152#	both	08/14/85
52	123-01	7 High Exer	JSC	II	61	90	other	01/04/89
53	121-01	7 High Exer	JSC	II	49	75	other	01/13/89
54	120-01	7 High Exer	JSC	I	81	78	both	11/09/88
55	117-01	7 High Exer	JSC	I	49	169	lower	09/27/88
56	121-02	7 Low Exer	JSC	I	65	109#	both	12/12/88
57	122-02	7 Low Exer	JSC	I	25	84	upper	01/13/89
58	146-02	8a	JSC	I	37	42#	lower	02/08/90
59	139-02	8a	JSC	I	novge	80	lower	11/21/89
60	147-01	8a	JSC	I	64	104	lower	01/25/90
61	138-01	8a	JSC	I	29	60	both	11/08/89
62	133-02	8a	JSC	I	41	105	lower	09/28/89
63	127-01	8a	JSC	I	63	129	lower	08/17/89
64	140-02	8a	JSC	I	40	60	both	11/21/89
65	149-01	8b	JSC	II	45	108	other	01/25/90
66	157-01	8b	JSC	I	novge	117#	upper	03/29/90
67	158-01	8b	JSC	I	56	111	lower	03/29/90
68	164-01	8b	JSC	I	44	79	lower	05/31/90
69	140-01	8b	JSC	I	20	97	both	11/08/89
70	139-01	8b	JSC	I	42	60	upper	11/08/89
71	137-02	8b	JSC	I	59	110#	lower	11/16/89
72	136-01	8b	JSC	I	37	40#	both	10/26/89
73	133-01	8b	JSC	I	25	137	lower	09/14/89
74	31-06	8b	JSC	I	76	144	lower	06/07/90
75	172-01	9a	JSC	I	173	179	lower	09/19/91
76	130-03	9b	JSC	I	52	---	lower	11/07/91
77	184-01	9b	JSC	II	novge	113	other	02/27/92

78	202-01	9c	JSC	I	38	94#	lower	03/17/94
79	204-01	9c	JSC	I	47	80#	lower	03/24/94
80	207-01	9c	JSC	I	62	165	lower	06/17/94
81	192-01	10	JSC	I	20	158	upper	10/07/92
82	215-01	11	JSC	I	96	144#	lower	12/12/96
83	228-01	11	JSC	I	101	153	lower	09/11/97
84	234-01	11	JSC	I	32	48	upper	02/19/98
85	D980113C	Phase I	Duke	I	75	76	lower	01/13/98
86	D980120B	Phase I	Duke	I	16	113	lower	01/20/98
87	D980203B	Phase I	Duke	I	74	111	both	02/03/98
88	D980210A	Phase I	Duke	I	novge	164	other	02/10/98
89	D980303B	Phase I	Duke	I	60	134	upper	03/03/98
90	H980219A	Phase I	Hermann	I	108	108	lower	02/19/98
91	H980226A	Phase I	Hermann	I	76	144	lower	02/26/98
92	H980310A	Phase I	Hermann	I	76	76	lower	03/10/98
93	H980324B	Phase I	Hermann	I	76	76	other	03/24/98
94	D980630B	Phase III	Duke	I	novge	52	lower	06/30/98
95	D980714C	Phase III	Duke	II	105	143	upper	07/14/98
96	H990511A	Phase IV	Hermann	I	novge	92	lower	05/11/99
97	H990527B	Phase IV	Hermann	I	64	84	lower	05/27/99
98	H990610A	Phase IV	Hermann	I	45	45	lower	06/10/99
99	H990615B	Phase IV	Hermann	I	169	183	lower	06/15/99
100	C990311B	Phase IV	DCIEM	I	31	31	lower	03/11/99
101	C990315D	Phase IV	DCIEM	I	40	56	lower	03/15/99
102	C990317D	Phase IV	DCIEM	I	93	118	lower	03/17/99
103	C990324C	Phase IV	DCIEM	I	40	92	lower	03/24/99

High EXER: High exercise with row machine during middle hour of 3-hour test.
Low EXER: Low exercise with row machine during middle hour of 3-hour test.
DCIEM: Defense and Civil Institute of Environmental Medicine, now designated Defense Research and Development Canada – Toronto.
DCS time: # indicates best elapsed time from start of test to when symptoms were first *noticed* but not reported; + indicates best elapsed time from start of test to when symptoms were first *noticed* after test was over, during formal debriefing; --- indicates no accurate time for DCS could be provided after test was over, during formal debriefing; and DCS time with no marking indicates best elapsed time from start of test to when symptoms were first *reported*.
Symptom site: upper indicates site of symptom(s) was localized in upper body (i.e., hand, wrist, elbow, shoulder, back, or head (except for unusual headache)); lower indicates site of symptom(s) was in lower body (i.e., foot, ankle, knee, or hip); both indicates that multiple symptoms were localized in both the upper and the lower body; and other indicates site of symptom(s) could not be classified as Type I "pain-only" DCS.

Case Descriptions of Hypobaric Decompression Sickness

Bends 1a: DCS Assigned at JSC

1. Summary: ID# 21-01, 34-year-old male, maximum Grade 3, first VGE at 46 minutes, first report at 44 minutes, study done on n = 11, independent sample statistical design.

Procedure 1. A technical problem with the airlock lid delayed decompression such that total PB time was extended from 3.5 to 4.0 hours for this subject, with all else the same as described under Procedure 1 in Appendix A.

Narrative: At 44 minutes, subject reported pain on top of right foot. Did not report initial pain score on the 1–10 scale since this scale was not yet implemented. At 118 minutes, he reported pain in right knee in addition to that in right foot. First VGE detected at 46 minutes, Grade 0 from left arm, Grade 0 from left leg, Grade 2 from right arm, and Grade 2 from right leg. Next VGE detected at 62 minutes, Grade 1 in left leg, Grade 1 in right arm and Grade 3 in right leg. Last VGE record at 112 minutes with Grade 0 from left arm, Grade 2 from left leg, Grade 2 from right arm, and Grade 3 from right leg. The MO decided to remove subject from the test, and repressurization began 131 minutes into the test. Symptoms in right foot and right knee resolved during descent at 5.9 psia.

Diagnosis: Grade 3 Type I DCS
Treatment: None, just observation at the JSC Clinic with follow-up consultation.

2. Summary: ID# 25-01, 32-year-old male, maximum Grade 4, first VGE at 27 minutes, first report at 49 minutes, study done on n = 11, independent sample statistical design.

Procedure 1

Narrative: At 49 minutes, subject reported pain in left foot. Did not report initial pain score on the 1–10 scale since this scale was not yet implemented. At 76 and 116 minutes, subject reported pain in left heel. First VGE detected at 27 minutes, Grade 0 from left arm, Grade 2 from left leg, Grade 3 from right arm, and Grade 2 from right leg. Last VGE record at 109 minutes with Grade 2 from left arm, Grade 4 from left leg, Grade 3 from right arm, and Grade 4 from right leg. The MO decided to remove subject from the test. Subject last reported at 124 minutes that he had continuous pain in left foot and left heel. Symptoms in left foot and left heel resolved during descent at 8.0 psia.

Diagnosis: Grade 3 Type I DCS
Treatment: None, just observation at the JSC Clinic with follow-up consultation.

3. Summary: ID# 26-01, 27-year-old male, maximum Grade 1, first VGE at 59 minutes, first report at 75 minutes, study done on n = 11, independent sample statistical design.

Procedure 1

Narrative: At 75 minutes, subject reported pain in left knee. Did not report initial pain score on the 1–10 scale since this scale was not yet implemented. First VGE detected at 59 minutes, Grade 0 from left arm, Grade 1 from left leg, Grade 0 from right arm, and Grade 0 from right leg. Last VGE record at 67 minutes with Grade 0 from left arm, Grade 1 from left leg, Grade 0 from right arm, and Grade 0 from right leg. The MO decided to end the test for this subject. Shortly after this decision was made, the second chamber mate (27-01) reported discomfort in right knee. Recompression of subject began 86 minutes from the start of the test. Symptoms in left knee resolved during descent at 6.0 psia.

Diagnosis: Grade 2 Type I DCS
Treatment: None, just observation at the JSC Clinic with follow-up consultation.

4. Summary: ID# 27-01, 39-year-old male, maximum Grade 2, first VGE at 47 minutes, first report at 76 minutes a symptom he noticed moments earlier, study done on n = 11, independent sample statistical design.

Procedure 1

Narrative: At 76 minutes, subject reported discomfort in right knee. Did not report initial pain score on the 1–10 scale since this scale was not yet implemented. Subject noticed discomfort at previous Doppler monitoring station. The exercise protocol was disrupted during the removal of a chamber mate (26-01) at 86 minutes due to pain in left knee. At 102 minutes, the logbook still indicated pain in right leg, specifically the right knee and right ankle. First VGE detected at 47 minutes, Grade 0 from left arm, Grade 0 from left leg, Grade 0 from right arm, and Grade 1 from right leg. Last VGE record at 102 minutes with Grade 0 from left arm, Grade 1 from left leg, Grade 0 from right arm, and Grade 3 from right leg. The MO decided to end the test. Repressurization was started about 102 minutes into the test. Symptoms resolved in right leg during descent at 7.2 psia.

Diagnosis: Grade 3 Type I DCS
Treatment: None, just observation at the JSC Clinic with follow-up consultation.

Bends 1b: DCS Assigned at JSC

5. Summary: ID# 12-01, 29-year-old male, maximum Grade 4, first VGE at 62 minutes, first report at 77 minutes, study done on n = 13, independent sample statistical design.

Procedure 2

Narrative: At 77 minutes, subject reported pain in right knee. Did not report initial pain score on the 1–10 scale since this scale was not yet implemented. First VGE detected at 62 minutes, Grade 0 from left arm, Grade 0 from left leg, Grade 0 from right arm, and Grade 3 from right leg. Last VGE record at 79 minutes with Grade 0 from left arm, Grade 0 from left leg, Grade 4 from

right arm, and Grade 4 from right leg. The exercise activities were interrupted while his chamber mate was removed for pain symptoms in the knees (11-01). The MO decided to abort this test earlier than the planned after 3 hours. Initiated repressurization at 81 minutes. Symptoms in right knee resolved during descent at 5.0 psia.

Diagnosis: Grade 3 Type I DCS
Treatment: None, just observation at the JSC Clinic with follow-up consultation.

6. Summary: ID# 11-01, 45-year-old male, maximum Grade 4, first VGE at 6 minutes, first report at 28 minutes a symptom he noticed earlier, study done on n = 13, independent sample statistical design.

Procedure 2

Narrative: At 28 minutes, subject reported pain in right knee and left knee. Did not report initial pain score on the 1–10 scale since this scale was not yet implemented. First VGE detected at 6 minutes, Grade 3 from left arm, Grade 4 from left leg, Grade 4 from right arm, and Grade 4 from right leg. Last VGE record at 23 minutes with Grade 3 from left arm, Grade 4 from left leg, Grade 4 from right arm, and Grade 4 from right leg. The MO decided to remove subject from the test; after 42 minutes, repressurization began. Symptoms resolved during descent in right knee at 5.27 psia and in left knee at 8.69 psia. During debrief, subject mentioned that he felt sensations in the knees long before he reported the symptoms, and that he felt a sharp pain while getting into the airlock for recompression. Pain at that time was a constant deep ache.

Diagnosis: Grade 3 Type I DCS
Treatment: None, just observation at the JSC Clinic with follow-up consultation.

7. Summary: ID# 2-01, 36-year-old male, maximum Grade 3, first VGE at 57 minutes, first report at 64 minutes a symptom he noticed moments earlier, study done on n = 13, independent sample statistical design.

Procedure 2

Narrative: At 64 minutes, subject reported pain in left knee. Did not report initial pain score on the 1–10 scale since this scale was not yet implemented. First VGE detected at 57 minutes, Grade 0 from left arm, Grade 3 from left leg, Grade 0 from right arm, and Grade 2 from right leg. This was also the last VGE monitoring period. Since the DT had also reported pain and fullness in the left knee at 44 minutes, the MO terminated the 3-hour test early. Initiated repressurization at 66 minutes. Both subject's and DT's symptoms in left knee resolved during descent at 12.0 psia.

Diagnosis: Grade 2 Type I DCS
Treatment: None, just observation at the JSC Clinic with follow-up consultation.

Bends Prevention Test Summary 7/22/82 (from PI)

Decompression to 10.2 psi was completed 7/21/82 at 06:15. 27% O_2 was reached in the ETA and 12 hour period at 10.2 psi was begun. The lock observer began his prebreathe at 03:30 and remained on O_2 until 6:45, a period of 3 hours and 15 minutes. At 07:26 the 12 hour period was completed and O_2 breathing was begun. At 8:06 the 40 minutes O_2 breathing was completed. At 08:12 decompression to 4.3 psi was begun. Decompression to 4.3 psi was completed at 08:19. The first exercise cycle began at 08:20 and was completed at 08:34. The DT and both subjects showed no bubbles and no symptoms. Between 08:34 and 08:37 Grade 3 bubbles were detected after movement of the DTs left leg and Grade 1 bubbles were detected after movement of the right leg and right arm. The DT had no symptoms. Between 08:39 and 08:47 both subjects were monitored. No bubbles were detected and no symptoms were reported. At 08:47 to 08:52 the DT was monitored and Grade 3 bubbles were detected after movement of the left leg and Grade 2 bubbles after movement of the right leg. Between 08:54 and 09:03 subjects 1 or 2 were monitored. No bubbles were detected real time and no symptoms were reported. Posttest tape review indicates a possible Grade 1 bubble after movement of subject 2 left leg. Between 09:03 and 09:09 the DT was monitored. Grade 2 bubbles were detected without limb movement. Grade 3 bubbles were detected after movement of the left arm and right leg. Grade 4 bubbles were detected after movement of the left leg and right arm. At 9:07 the DT reported slight transitory pain in the left knee. Between 9:09 and 9:12 subject 1 was monitored and real time Grade 1 was detected after movement of the right leg. Posttest review of the tape indicated this was an artifact, not a bubble. There were no symptoms. The DT was monitored from 9:12 to 9:15. Grade 3 bubbles were detected after movement of the left arm and right leg. Grade 4 bubbles were detected after movement of the left leg and right arm. Symptoms were reported to be about the same as before, but not definite. Between 9:16 and 9:18 subject 2 was monitored and Grade 3 bubbles were detected after movement of the left leg and Grade 2 bubbles after movement of the right leg. Subject had not reported symptoms. At 09:18 to 09:22 the DT was monitored and Grade 3 bubbles were detected without movement. With movement, strong Grade 4 bubbles with heavy showers were measured. The DT then reported fullness in the left knee, like a sprain. Subject 2 then (09:23) reported mild pain in the left knee that had started during his last exercise period (09:16 to 09:18). At 09:25 the decision was made by the MO to terminate the test. At 09:34, at 12 psi, both subject #2 and the DT reported symptoms gone. At 09:36 subject #2 was monitored and no bubbles were detected. At 09:38 the DT was monitored and Grade 3 bubbles were detected after movement of the left leg. At 9:40 the ETA reached 14.7 psi. At 9:51 the DT was monitored again and no bubbles were detected at 09:55. Subject #2 and the DT were taken to the clinic for surveillance.

Bends 1c: DCS Assigned at JSC

8. Summary: ID# 20-01, 34-year-old male, maximum Grade 4, first VGE at 19 minutes, first report at 76 minutes, study done on n = 12, independent sample statistical design.

Procedure 3. Same as Procedure 3 except subject spent 4 minutes flexing hip and knee joints by rhythmically stepping in place once every 10 seconds, instead of stepping on an 18.4-cm step once every 10 seconds for 4 minutes.

Narrative: At 76 minutes, subject reported discomfort in right knee. Did not report initial pain score on the 1–10 scale since this scale was not yet implemented. First VGE detected at 19 minutes, Grade 0 from left arm, Grade 0 from left leg, Grade 2 from right arm, and Grade 2 from right leg. Last VGE record at 68 minutes with Grade 3 from left arm, Grade 3 from left leg, Grade 4 from right arm, and Grade 4 from right leg. The MO decided to remove subject from the test. At 96 minutes, discomfort in right knee had gone before subject entered the airlock, but returned when he stepped into the airlock and was present prior to repressurization. Symptoms in right knee resolved during descent at 8.30 psia.

Diagnosis: Grade 3 Type I DCS
Treatment: None, just observation at the JSC Clinic with follow-up consultation.

9. Summary: ID# 19-01, 37-year-old male, maximum Grade 4, first VGE at 25 minutes, first report at 78 minutes, study done on n = 12, independent sample statistical design.

Procedure 3

Narrative: At 78 minutes, subject reported a short pain in right knee that went away while stepping. Did not report initial pain score on the 1–10 scale since this scale was not yet implemented. At 104 minutes, subject reported slight discomfort in right knee; level remained constant. First VGE detected at 25 minutes, Grade 0 from left arm, Grade 0 from left leg, Grade 3 from right arm, and Grade 0 from right leg. Last VGE record at 109 minutes with Grade 2 from left arm, Grade 4 from left leg, Grade 4 from right arm, and Grade 4 from right leg. At 116 minutes subject, reported intermittent discomfort or low-level pain or awareness in right knee. The MO decided to abort the 3-hour test after 120 minutes of exposure after subject's chamber mate also developed symptoms in right knee (18-01). Symptoms in right knee resolved during descent at 7.3 psia.

Diagnosis: Grade 2 Type I DCS
Treatment: None, just observation at the JSC Clinic with follow-up consultation.

10. Summary: ID# 18-01, 33-year-old male, maximum Grade 4, first VGE at 69 minutes, first report at 104 minutes, study done on n = 12, independent sample statistical design.

Procedure 3

Narrative: At 104 minutes, subject reported slight discomfort in right knee. At 116 minutes, he reported intermittent discomfort or low-level pain awareness in right knee. Did not report initial pain score on the 1–10 scale since this scale was not yet implemented. Grade 4 VGE were detected 87 minutes into the test after flexing right leg, and again at 101 minutes when right leg or left leg was flexed. First VGE detected at 69 minutes, Grade 0 from left arm, Grade 0 from left leg, Grade 0 from right arm, and Grade 1 from right leg. Last VGE record at 101 minutes with Grade 1 from left arm, Grade 2 from left leg, Grade 4 from right arm, and Grade 4 from right leg. The MO decided to abort the 3-hour test after 120 minutes of exposure after subject's chamber mate also developed symptoms in right knee (19-01). Symptoms in right knee resolved during descent at 7.3 psia.

Diagnosis: Grade 2 Type I DCS
Treatment: None, just observation at the JSC Clinic with follow-up consultation.

11. Summary: ID# 15-01, 28-year-old male, maximum Grade 4, first VGE at 37 minutes, first report after the end of the test during debrief, estimated at 166 minutes into the test, study done on n = 12, independent sample statistical design.

Procedure 3

Narrative: During debrief, subject mentioned that he felt some pain during the last round of exercise at about 166 minutes in his right ankle, and that there was a sharp pain below both knee caps just prior to descent. Did not report initial pain score on the 1–10 scale since this scale was not yet implemented. First VGE detected at 37 minutes, Grade 0 from left arm, Grade 0 from left leg, Grade 0 from right arm, and Grade 1 from right leg. Last VGE record at 181 minutes with Grade 0 from left arm, Grade 3 from left leg, Grade 2 from right arm, and Grade 3 from right leg. Symptoms in both knees and right ankle resolved during descent at 12.2 psia, as estimated from the posttest comments.

Diagnosis: Grade 2 Type I DCS
Treatment: None, just self-monitoring most likely with follow-up consultation.

Bends 1d: DCS Assigned at JSC

12. Summary: ID# 11-02, 45-year-old male, maximum Grade 4, first VGE at 34 minutes, first report after the end of the test during debrief, estimated at 50 minutes into the test, study done on n = 3, independent sample statistical design.

Procedure 4

Narrative: During debrief, subject mentioned that after 3rd or 4th exercise period he felt something in his knees. This would have been about 50 minutes into the test. Did not report initial pain score on the 1–10 scale since this scale was not yet implemented. He said that the sensations in his knees did go away on return to site pressure. He compared symptoms in left and right shins, and intermittent pain in the knees as a different type of pain to that he had experienced on a previous exposure (11-01), 2 days earlier. It was a much milder pain than before. First VGE detected at 34 minutes, Grade 1 from left arm, Grade 3 from left leg, Grade 0 from right arm, and Grade 3 from right leg. Last VGE record at 177 minutes with Grade 3 from left arm, Grade 4 from left leg, Grade 4 from right arm, and Grade 4 from right leg. Symptoms in both knees and shins resolved during descent at site pressure, as revealed during debriefing.

Diagnosis: Grade 2 Type I DCS
Treatment: None, just self-monitoring most likely with follow-up consultation.

13. Summary: ID# 10-02, 44-year-old male, maximum Grade 4, first VGE at 62 minutes, first report after the end of the test during debrief, estimated at 60 minutes into the test, study done on n = 3, independent sample statistical design.

Procedure 4

Narrative: During debrief, subject mentioned that after about 60 minutes into the test he experienced a symptom in right leg. Symptom was clear during the last hour of the 3-hour test. Did not report initial pain score on the 1–10 scale since this scale was not yet implemented. First

VGE detected at 62 minutes, Grade 0 from left arm, Grade 1 from left leg, Grade 1 from right arm, and Grade 2 from right leg. Last VGE record at 174 minutes with Grade 0 from left arm, Grade 1 from left leg, Grade 3 from right arm, and Grade 4 from right leg. There were no symptoms prior to descent; symptoms resolved at the test altitude of 4.3 psia.

Diagnosis: Grade 2 Type I DCS
Treatment: None, self-monitoring most likely with follow-up consultation.

Bends 2a: DCS Assigned at JSC

14. Summary: ID# 37-02, 26-year-old male, maximum Grade 4, first VGE at 55 minutes, first report at 59 minutes, study done on n = 23, independent sample statistical design.

Procedure 5

Narrative: At 59 minutes, subject reported momentary pain in right knee; pain was gone at 1st-hour questioning. Reported initial pain score of 1 on a 1–10 scale. At 106 minutes, subject reported an occasional twinge in right knee. At 218 minutes, subject reported continuing twinges in right knee; level remained constant at 1. The exercise protocol was briefly interrupted as his chamber mate (21-02) was returned to site pressure at 177 minutes for pain in left knee and left ankle. First VGE detected at 34 minutes, Grade 0 from left arm, Grade 0 from left leg, Grade 0 from right arm, and Grade 3 from right leg. Last VGE record at 176 minutes with Grade 0 from left arm, Grade 0 from left leg, Grade 0 from right arm, and Grade 4 from right leg. The 4-hour test was completed. Logbook indicated that subject was clear of symptoms in right knee on the way to site pressure. During debrief, subject indicated mild right knee pain for most of the test and an itch on right thigh for about half an hour during test. Pain diminished with descent, but rash mark still remained at location of itch. Subject mentioned that there was still very slight discomfort in right knee.

Diagnosis: Grade 2 Type I DCS, CM cannot be ruled out
Treatment: None, medical observation for 12 hours with follow-up consultation.

15. Summary: ID# 35-02, 43-year-old male, maximum Grade 4, first VGE at 116 minutes, first report at 116 minutes a symptom he noticed moments earlier, study done on n = 23, independent sample statistical design.

Procedure 5

Narrative: At 116 minutes, subject reported pain in arch of right foot. Reported initial pain score of 4 on a 1–10 scale. He noticed symptom earlier, just before going to the Doppler monitoring station. At 177 minutes, the level decreased to 3–4; and by 243 minutes, subject reported pain in both knees, the level had decreased to 2. His chamber mate (38-03) reported discomfort in left knee at 221 minutes. First VGE detected at 116 minutes, Grade 0 from left arm, Grade 0 from left leg, Grade 0 from right arm, and Grade 2 from right leg. Last VGE record at 196 minutes with Grade 0 from left arm, Grade 0 from left leg, Grade 3 from right arm, and Grade 4

from right leg. Symptoms in both knees, arch of right foot, and right ankle resolved during descent at 8.81 psia. During debrief, subject mentioned that pain in arch of right foot moved up into right ankle, and it felt like a strain in the joint. He favored right knee at first, but was able to do the assigned exercise. Pain then spread to right knee. Intensity of the pain decreased with time. It was mentioned that pain in the knee (or knees) decreased when he was in the reclined position, and decreased when he bent his knee (or knees).

Diagnosis: Grade 2 Type I DCS
Treatment: None, medical observation most likely for 12 hours with follow-up consultation.

16. Summary: ID# 21-02, 34-year-old male, maximum Grade 4, first VGE at 105 minutes, first report at 76 minutes, study done on n = 23, independent sample statistical design.

Procedure 5

Narrative: At 76 minutes, subject reported pain in left ankle. Reported initial pain score of 1 on a 1–10 scale. At 117 minutes, subject reports dull ache in left knee; level remained constant at 1, but increased to a pain score of 7 at 148 minutes with pain reported in left knee and left ankle, with pain blending together. His chamber mate (37-02) had reported a momentary pain in right knee at 59 minutes. First VGE detected at 105 minutes, Grade 0 from left arm, Grade 4 from left leg, Grade 0 from right arm, and Grade 3 from right leg. Last VGE record at 122 minutes with Grade 0 from left arm, Grade 3 from left leg, Grade 0 from right arm, and Grade 2 from right leg. The MO decided to remove subject from the test. At 166 minutes, subject reported continuous pain in left knee and left ankle, but pain score had reduced to 3. Repressurization was started 177 minutes into the 4-hour test. Symptoms in left ankle and left knee resolved during descent at 7.1 psia.

Diagnosis: Grade 3 Type I DCS
Treatment: None, medical observation for 12 hours with follow-up consultation.

17. Summary: ID# 34-01, 30-year-old male, maximum Grade 4, first VGE at 77 minutes, first report of a symptom was after the test, and estimated to be 42 minutes into the test, study done on n = 23, independent sample statistical design.

Procedure 5. Same as Procedure 5 except the PB was extended by 30 minutes because a bad airlock seal interfered with the ETA pump down.

Narrative: Subject did not report symptoms during test. During debrief, subject mentioned a dull pain in right knee at about 42 minutes, also a twinge in left knee for which no time was documented. Subject did not report initial pain score on the 1–10 scale. At 119 minutes, pain score increased to 5; and by 228 minutes, pain score decreased to 2, for right knee. At 139 minutes, subject had Grade 4 VGE during all limb movements. First VGE detected at 77 minutes, Grade 0 from left arm, Grade 0 from left leg, Grade 2 from right arm, and Grade 0 from right leg. Last VGE record at 218 minutes with Grade 0 from left arm, Grade 3 from left leg, Grade 1 from right arm, and Grade 2 from right leg. Prior to return to site pressure, at 4 hours he still had

symptoms in left knee and right knee because he said pain had resolved during return to site pressure. Symptoms in both knees resolved at 7.34 psia during descent, based on debrief estimate. It is unclear from the logbook if subject still had awareness in both knees at site pressure. Within 2 hours of the conclusion of test, subject reported pain in both knees.

Diagnosis: Grade 2 Type I DCS
Treatment: USN TT V for reoccurrence of symptoms. Pain was relieved on the compression. Medical observation for 12 hours with follow-up consultation.

18. Summary: ID# 5-02, 29-year-old male, maximum Grade 4, first VGE at 104 minutes, first report at 160 minutes, study done on n = 23, independent sample statistical design.

Procedure 5

Narrative: At 160 minutes, subject reported some pain and discomfort in right knee and right foot. Reported initial pain score of 7 on a 1–10 scale. He described pain in right foot as a muscle cramp, and pain in right knee as sharp when standing. Right knee pain was localized outside the joint. It went to a pain score of 2 when standing on the floor at rest, but increased to a 7 when walking from station to station. At 177 minutes, level remained constant at 7; and at 223 minutes, level was still constant at 7. First VGE detected at 104 minutes, Grade 0 from left arm, Grade 0 from left leg, Grade 0 from right arm, and Grade 2 from right leg. Last VGE record at 222 minutes with Grade 0 from left arm, Grade 0 from left leg, Grade 0 from right arm, and Grade 4 from right leg. Symptoms in right knee and right foot resolved during descent at 9.35 psia. During debrief, it appeared that subject had a tendency to favor right knee, but this did not interfere with his exercise activities. Pain in right foot was localized in the arch or instep, where he sometimes gets cramps.

Diagnosis: Grade 2 Type I DCS
Treatment: None, medical observation most likely for 12 hours with follow-up consultation.

19. Summary: ID# 32-01, 29-year-old male, maximum Grade 4, first VGE at 18 minutes, first report at debrief, but no indication of when during the test the symptoms first appeared, study done on n = 23, independent sample statistical design.

Procedure 5

Narrative: Subject did not report symptoms during test. During debrief, subject indicated very mild pain, more like stiffness in right knee and right foot, but no time was documented. Did not report initial pain score on the 1–10 scale. He mentioned that there was no pain at all during 4th-hour questioning, but that stiffness (unclear if this is for right knee, right foot, or both) went away on recompression to site pressure. This was his first indication that his symptoms might be related to decompression to 4.3 psia. First VGE detected at 18 minutes, Grade 0 from left arm, Grade 0 from left leg, Grade 0 from right arm, and Grade 3 from right leg. Last VGE record at 230 minutes with Grade 0 from left arm, Grade 0 from left leg, Grade 0 from right arm, and

Grade 3 from right leg. Symptoms resolved during descent, but exact altitude was not noted. Symptoms from right foot and right knee were gone at site pressure.

Diagnosis: Grade 1 Type I DCS
Treatment: Not clear if HBO was provided in this case, but there would be a follow-up consultation.

20. Summary: ID# 38-03, 33-year-old male, maximum Grade 3, first VGE at 216 minutes, first report at 221 minutes, study done on n = 23, independent sample statistical design.

Procedure 5

Narrative: At 221 minutes, subject reported discomfort, but not pain, in left knee along the lateral aspect. Reported initial pain score of less than 1 on a 1–10 scale. At 243 minutes, subject reported that pain scale was 1. His chamber mate (35-02) reported a pain in arch of the right foot at 116 minutes. First VGE detected at 216 minutes, Grade 0 from left arm, Grade 3 from left leg, Grade 1 from right arm, and Grade 0 from right leg. Last VGE record at 232 minutes with Grade 0 from left arm, Grade 3 from left leg, Grade 0 from right arm, and Grade 0 from right leg. There were no symptoms prior to descent; symptoms resolved at the test altitude of 4.3 psia. During debrief, subject mentioned that symptom in left knee was an awareness.

Diagnosis: Grade 1 Type I DCS
Treatment: None, just self-monitoring most likely with follow-up consultation.

Bends 2b: DCS Assigned at JSC

21. Summary: ID# 35-03, 43-year-old male, maximum Grade 4, first VGE at 34 minutes, first report at 17 minutes, study done on n = 22, independent sample statistical design.

Procedure 6

Narrative: At 17 minutes, subject reported deep pain in left knee. Reported initial pain score of 7 on a 1–10 scale. He reported that this symptom was similar to one he experienced in right foot and right knee on a previous test (35-02) where symptoms were present at about 116 minutes. At 34 minutes and 60 minutes, level remained constant at 7, but did not interfere with his activities. Pain score intensity decreased to 3 at 81 minutes and 110 minutes. During 3rd-hour questioning, subject reported that pain score increased to 6–7, left leg seemed weaker, and pain occupied the entire left knee. At 201 minutes, subject reported again that left leg seemed to be getting weak, on a pain scale of 9, but felt he could get through the last hour. At 4th-hour questioning, subject reported there was no change in left knee symptoms from the last report; a pain score of 9 at 240 minutes. First VGE detected at 34 minutes, Grade 0 from left arm, Grade 4 from left leg, Grade 1 from right arm, and Grade 2 from right leg. Last VGE record at 228 minutes with Grade 0 from left arm, Grade 0 from left leg, Grade 0 from right arm, and Grade 0 from right leg. Symptoms improved during descent but did not clear completely at site pressure. During debrief, subject

mentioned that left knee was not hurting, and strength had returned to left leg. Pain score was about 1 initially at site pressure; 16 minutes after the start of repressurization to site pressure, all symptoms were gone. He said that lying down made pain in his left knee worse to the point where he sat up during any rest period and after Doppler monitoring. During the greatest discomfort, at a pain score of 9, he had trouble walking. Finally, pain in left knee noticeably lessened at about 10.5 psia.

Diagnosis: Grade 3 Type I DCS
Treatment: None, medical observation most likely for 12 hours with follow-up consultation.

22. Summary: ID# 34-02, 31-year-old male, maximum Grade 4, first VGE at 69 minutes, first report at 236 minutes a symptom he noticed at 206 minutes, study done on n = 22, independent sample statistical design.

Procedure 6

Narrative: At 236 minutes, subject reported minor aches and pains in right knee and left knee, with right knee symptoms more noticeable. Reported initial pain score of 2 on a 1–10 scale. Symptoms had started about 30 minutes earlier (206 minutes) and were localized beneath the patella of both knees. His chamber mate (31-03) had reported symptoms in right arm at 180 minutes. First VGE detected at 69 minutes, Grade 0 from left arm, Grade 3 from left leg, Grade 1 from right arm, and Grade 2 from right leg. Last VGE record at 233 minutes with Grade 3 from left arm, Grade 4 from left leg, Grade 4 from right arm, and Grade 4 from right leg. Logbook did not indicate if symptoms in both knees improved during repressurization to site pressure. During debrief, subject mentioned that his knees felt better, but there was still some residual awareness like what you would experience after a good run. Subject had a previous chamber test (34-01) where symptoms were present but reported after the test. Debrief notes indicated he had a reoccurrence of symptoms in his knees and was treated 1.0–1.5 hours after debrief.

Diagnosis: Grade 2 Type I DCS
Treatment: USN TT V for reoccurrence of symptoms. Symptoms disappeared at the 60-foot level on treatment, plus a follow-up consultation.

23. Summary: ID# 31-03, 31-year-old male, maximum Grade 1, first VGE at 144 minutes, first report at 180 minutes, study done on n = 22, independent sample statistical design.

Procedure 6

Narrative: At 180 minutes, subject reported right arm felt different than left arm, meaning symptom was in right arm. Reported initial pain score of 1 on a 1–10 scale, as determined from debrief comments. At 207 and 236 minutes, level remained constant at 1. His chamber mate (34-02) had reported symptoms in right knee and left knee at 236 minutes. First VGE detected at 144 minutes, Grade 0 from left arm, Grade 1 from left leg, Grade 0 from right arm, and Grade 0 from right leg. Last VGE record at 236 minutes with Grade 0 from left arm, Grade 0 from left leg, Grade 0 from right arm, and Grade 0 from right leg. During 4th-hour questioning, subject

mentioned that he had a cramp in left foot, but attributed problem to his shoes; cramp was improved when he took his shoes off. Symptoms in right arm resolved during descent at 5.45 psia. During debrief, there was some question if symptom in right arm had gone before the re-pressurization, or if it cleared on the way to 25,000 feet (5.45 psia). Location of symptom was in forearm of right arm, and was not exercise related in that the feeling was not exacerbated during arm exercise and the symptoms were very intermittent.

Diagnosis: Grade 1 Type I DCS
Treatment: None, medical observation most likely for 12 hours with follow-up consultation.

24. Summary: ID# 3-03, 29-year-old male, maximum Grade 4, first VGE at 76 minutes, first report at 175 minutes, study done on n = 22, independent sample statistical design.

Procedure 6

Narrative: At 175 minutes, subject reported no aches or pains, but felt a heaviness in his legs, like blood pooling. Reported initial pain score of 1 on a 1–10 scale. At 209 minutes, he was more specific in that lower right leg felt like it had poor circulation; no particular area hurt. Assigned a pain score of 2 to right heel; classified symptom as an awareness. Massaging right leg and right foot seemed to make them feel better. Right heel and top front of right shin had diffuse sensations. Right knee was also reported to have an awareness or fullness, like poor circulation, at this time. At 4th-hour questioning, subject reported the same numbness, toes cold like you experience with lack of circulation. Still had an awareness of symptoms that were accentuated by right leg movements. He assigned pain score of 2 for his symptoms at 241 minutes. First VGE detected at 76 minutes, Grade 0 from left arm, Grade 0 from left leg, Grade 1 from right arm, and Grade 2 from right leg. Last VGE record at 236 minutes with Grade 1 from left arm, Grade 2 from left leg, Grade 2 from right arm, and Grade 4 from right leg. Symptoms of cold right foot and numbness resolved during descent at approximately 6.75 psia. During debrief, subject mentioned that symptoms during this test were like symptoms on his first 10.2-psia test (test designation 1b, 3-01), but no DCS was diagnosed during that test. This was 3rd time subject had participated in a chamber test, and the 1st time he reported symptoms. He mentioned that ball of right foot had cramped. Symptoms were described as diffuse, moving around right leg. Also mentioned that he was fatigued toward the end of the test.

Diagnosis: Grade 1 Type I DCS
Treatment: None, medical observation most likely for 12 hours with follow-up consultation.

25. Summary: ID# 21-03, 34-year-old male, maximum Grade 4, first VGE at 37 minutes, first report at 160 minutes, study done on n = 22, independent sample statistical design.

Procedure 6

Narrative: At 160 minutes, subject reported pain, ache, and some stabbing in left shoulder. Reported initial pain score of 2 on a 1–10 scale. For completeness, he also reported a slight ache in one of his teeth when the test at 4.3 psia first began. At 3rd-hour questioning, he said pain in

left shoulder was gone, but was at a pain score of 1 on the last exercise activity. At about 210 minutes, subject reported a stabbing type of pain had appeared in left ankle during last exercise activity; gave this a pain score of 2 at about 201 minutes. Pain in left ankle had decreased to a pain score of 1–2 at 239 minutes. First VGE detected at 37 minutes, Grade 3 from left arm, Grade 0 from left leg, Grade 0 from right arm, and Grade 0 from right leg. Last VGE record at 240 minutes with Grade 3 from left arm, Grade 3 from left leg, Grade 0 from right arm, and Grade 0 from right leg. Symptoms in left ankle resolved during descent at 5.45 psia. Subject had 2 previous tests (21-01 and 21-02) where symptoms were present.

Diagnosis: Grade 2 Type I DCS
Treatment: None, medical observation most likely for 12 hours with follow-up consultation.

26. Summary: ID# 18-02, 33-year-old male, maximum Grade 4, first VGE at 1 minutes, first report at 65 minutes, study done on n = 22, independent sample statistical design.

Procedure 6

Narrative: At 65 minutes, subject reported discomfort and pain in right knee. Reported initial pain score of 1 on a 1–10 scale. At 103 minutes, level increased to 2–3. Grade 1 VGE were detected 1 minute into the test after flexing right leg. Grade 4 VGE were detected at 17 minutes after flexing right leg. Grade 4 VGE were detected from all limbs at 52 minutes and at 92 minutes. Subject in a previous test (18-01) reported discomfort in right knee at 104 minutes. Last VGE record at 92 minutes with Grade 4 from left arm, Grade 4 from left leg, Grade 4 from right arm, and Grade 4 from right leg. At 103 minutes, subject reported sudden onset of fatigue and cold sweat. At the same time, red and white mottling or marbling appeared on chest. Skin mottling was diagnosed 103 minutes into the exposure. Accumulation and rapid onset of signs and symptoms initiated removal of subject through a smaller transfer airlock at 115 minutes. Pain in right knee and feeling of fatigue cleared at 7.2 psia. Mottling disappeared in 10 minutes at site pressure on 100% O_2. During debrief, subject mentioned that fatigue was very significant and he felt it would interfere with his ability to perform the exercise protocol.

Diagnosis: Type II DCS (at this time, CM by itself was also classified as Type II DCS at JSC)
Treatment: Two-hour GLO. Subject was held in a horizontal position while on 100% O_2 for 2 hours and was under medical observation in a hyperbaric chamber overnight. There were no further symptoms or indication of neurological deficit during follow-up consultation.

A 33-year-old male, 62.6 kg, 167 cm, with 15% computed body fat and 22.4 BMI [body mass index], participated in an altitude exposure at JSC. Subject had one previous altitude exposure as a research subject to evaluate the effectiveness of a staged decompression protocol to prevent DCS during extravehicular activity from the Space Shuttle. A brief description of the first test is warranted. Subject ascended to 10.2 psia in about 2 minutes, and the chamber atmosphere was enriched to 26.5% O_2. There was minimal physical activity, including sleep, during the 12 hour exposure. A 90 minutes O_2 PB with a 4 minutes ascent preceded a 3 hour exposure to 4.3 psia. Exercise stressed the lower body since 4 minutes were spent flexing the ankle, knee, and hip joints by rhythmically stepping onto an 18.4-cm step once every 10 seconds. This was followed by 4 minutes of flexing the wrist, elbow, and shoulder joints by rhythmically lifting a 1.36 kg weight alternately every 5 seconds from left to right hand. Finally, there was a 4 minutes period of rest and a 4 minutes period of bubble monitoring with subject asked to flex each limb in turn while in a supine position. Bubble monitoring was provided by a DT trained to detect the blood flow signal in the pulmonary artery, at the precordial position, using an ultrasound Doppler bubble detector. Subject ambulated to

the 2 exercise stations within the chamber. Grade IV VGE were detected 87 minutes into the test after flexing the right leg, and again at 101 minutes when the right or left leg was flexed. Subject reported pain in the right knee at 116 minutes, and the test was aborted at 118 minutes for an unrelated reason. The pain in the right knee cleared at 7.3 psia during the repressurization to site pressure. Several changes were made to the staged decompression protocol, and subject was willing to participate again. Five months later subject again ascended to 10.2 psia in about 5 minutes, and the chamber atmosphere was once again enriched to 26.5% O_2. There was minimal physical activity, including sleep, during the 12 hour exposure. A 40 minutes O_2 PB with a 25 minutes ascent preceded a 4 hour exposure to 4.3 psia. Exercise stressed the upper body since 4 minutes were spent flexing the wrist, elbow, and shoulder joints while rhythmically rotating the wheel of a bicycle ergometer against a set resistance from a standing position, 4 minutes torquing fixed bolts with either the left or right hand from a standing position, and 4 minutes of rhythmically pulling against a set resistance from a seated position. Additional details about the exercises are available. Finally, there was a 4 minutes period of rest and a 4 minutes period of bubble monitoring with the subject asked to flex each limb in turn while in a supine position. Subject ambulated to the three exercise stations within the chamber. Grade I VGE were detected 1 minutes into the test after flexing the right leg. Grade IV VGE were detected at 17 minutes after flexing the right leg. Grade IV VGE were detected from all limbs at 52 minutes and at 92 minutes. Subject reported pain in the right knee after 57 minutes. At 103 minutes subject reported sudden onset of fatigue, and cold sweat. At the same time, red and white mottling or marbling appeared on the chest. Skin mottling was diagnosed 103 minutes into the exposure. The accumulation and rapid onset of signs and symptoms initiated the removal of subject through a smaller transfer airlock at 115 minutes. Pain and feeling of fatigue cleared at 7.2 psia. Mottling disappeared in 10 minutes at site pressure on 100% O_2. Subject was held in a horizontal position while on 100% O_2 for 2 hour and was under medical observation in a hyperbaric chamber over night. There were no further symptoms or indication of neurological deficit.

Bends 3a: DCS Assigned at JSC

27. Summary: ID# 42-02, 28-year-old male, maximum Grade 4, first VGE at 34 minutes, first report at 356 minutes a symptom he first noticed at about 294 minutes, study done on n = 28, independent sample statistical design.

Procedure 7

Narrative: At 356 minutes, during 6th-hour questioning, subject reported minor ache in right knee. Reported initial pain score of 4 on a 1–10 scale that went to a pain score of 2, but this was for symptom he experienced earlier in the test. Symptom was present on the cot at the Doppler monitoring station. He noticed this symptom about 2.5 exercise rotations earlier, or at about 294 minutes. His chamber mate (44-02) had reported symptom at 68 minutes of very mild discomfort in the right knee. First VGE detected at 34 minutes, Grade 0 from left arm, Grade 0 from left leg, Grade 0 from right arm, and Grade 3 from right leg. Last VGE record at 356 minutes with Grade 1 from left arm, Grade 0 from left leg, Grade 2 from right arm, and Grade 2 from right leg. At continuation of 6th-hour questioning, subject reported ache in right knee was not present at that time. There were no symptoms prior to descent; symptoms resolved at the test altitude of 4.3 psia. During debrief at site pressure, subject mentioned pain in right knee was continuous for about 20 minutes; initially a sharp clear pain for about 30 seconds, then went from a pain score of 4–5 to about 1–2, and was worse when standing and exercising at the arm ergometer.

Diagnosis: Grade 2 Type I DCS
Treatment: None, medical observation most likely for 12 hours with follow-up consultation.

28. Summary: ID# 47-01, 26-year-old male, maximum Grade 4, first VGE at 4 minutes, first report at 60 minutes a symptom he noticed at 50 minutes, study done on n = 28, independent sample statistical design.

Procedure 7

Narrative: At 60 minutes, during 1st-hour questioning, subject reported pain that came and went in left knee and was worse when lying down. Reported initial pain score of 4 on a 1–10 scale. He recalled that symptom was noticed about 10 minutes earlier, and did not interfere with his exercise activities. Pain score remained constant at 4 during 2nd-hour questioning, and again a pain score of 4 at 179 minutes. During 3rd-hour questioning, pain was described as intermittent, and noticed in left knee while he was lying down with movement of the limb and ankle during the Doppler monitoring. At 4th-hour questioning, subject reported no change in left knee pain, but now both ankles had a continuous pain; no pain score was given for ankles. Left knee had a pain score of 1 at this time. At 5th-hour questioning, subject reported no further pain in left knee, just a bit of mild continuous stiffness in ankles. At 6th-hour questioning, pain in ankles was still present. First VGE detected at 4 minutes, Grade 0 from left arm, Grade 4 from left leg, Grade 0 from right arm, and Grade 2 from right leg. Last VGE record at 355 minutes with Grade 0 from left arm, Grade 0 from left leg, Grade 0 from right arm, and Grade 2 from right leg. Symptoms in ankles resolved during descent at 6.33 psia on the way to site pressure.

Diagnosis: Grade 2 Type I DCS
Treatment: None, medical observation most likely for 12 hours with follow-up consultation.

29. Summary: ID# 46-01, 50-year-old male, maximum Grade 4, first VGE at 76 minutes, first report at 303 minutes a symptom he noticed at 120 minutes, study done on n = 28, independent sample statistical design.

Procedure 7

Narrative: At 303 minutes, during 5th-hour questioning, subject reported a little bit of pain in right knee. Reported initial pain score of 1–2 on a 1–10 scale. He first felt something in right knee at about 120 minutes, but feeling went away. It was back now and was continuous, but got better when he walked. His chamber mate (13-04) had reported symptom in the left knee at 205 minutes. First VGE detected at 76 minutes, Grade 2 from left arm, Grade 0 from left leg, Grade 0 from right arm, and Grade 0 from right leg. Last VGE record at 355 minutes with Grade 0 from left arm, Grade 3 from left leg, Grade 0 from right arm, and Grade 2 from right leg. At 6th-hour questioning, subject reported right knee discomfort was same as before, and left ankle pain had gone. This was first indication that there was a symptom in left ankle. Symptoms in right knee resolved during descent at 5.66 psia. During debrief at site pressure, subject said he did not report initial sensations in right ankle and right knee until they reoccurred later in the test. The logbook mentions there was a very clear remission of right knee symptoms during repressurization to site pressure. This description is inconsistent, however, since left ankle symptom mentioned at 6th-hour questioning was not mentioned during debrief, and right ankle symptom mentioned during debrief was never mentioned (documented) during test. What seems clear is that an ankle along with the right knee had symptoms.

Diagnosis: Grade 2 Type I DCS
Treatment: None, medical observation most likely for 12 hours with follow-up consultation.

30. Summary: ID# 44-02, 36-year-old male, maximum Grade 4, first VGE at 42 minutes, first report at 68 minutes a symptom he noticed moments before, study done on n = 28, independent sample statistical design.

Procedure 7

Narrative: At 68 minutes, subject reported very mild discomfort in right knee. Reported initial pain score of 1 on a 1–10 scale. For completeness, subject reported tingling sensations in thighs at 29 minutes. At 1st-hour questioning, subject mentioned symptoms in right knee had been present for the last couple of minutes, and were a continuous mild discomfort. There was no tingling in thighs at this time, and he suspected symptom was due to being warm. Pain score remained constant at 1 at 105, 119, and 165 minutes. Pain score only increased to 2 after 180 minutes. At 108 minutes, subject reported that pain was better localized, and was pain rather than discomfort on the right side of right patella. At 120 minutes, pain was reported to be a little less than it had been at previous report at 108 minutes, and was less painful compared to his previous exposure (44-01). At 125 minutes, pain score was 2 while straightening right leg during Doppler monitoring. At 3rd-hour questioning, reported that right ankle discomfort was gone from that noticed at 2nd hour. This was first indication in the logbook that he had a symptom in right ankle. Right knee pain was unchanged from 2nd hour. Left knee also has general discomfort, noticed about 15 minutes earlier, now at a pain score less than 1. Symptoms did not interfere with the exercise protocol. Pain score decreased back to 1 at 238, 289, 297, 327, and 359 minutes. First VGE detected at 42 minutes, Grade 0 from left arm, Grade 2 from left leg, Grade 0 from right arm, and Grade 1 from right leg. Last VGE record at 364 minutes with Grade 0 from left arm, Grade 2 from left leg, Grade 0 from right arm, and Grade 3 from right leg. At 4th-hour questioning, right knee pain was less, left knee discomfort was almost gone, with joints aggravated with movement but not noticeable when motionless. At 291 minutes, there was still discomfort in left knee, also pain in shin about one inch below left knee. Right knee still had pain when joint was moved, but no pain when joint was motionless. At 299 minutes, there was no discomfort in right knee, but some present in left knee; gave pain score of 1 for the shin just below left knee. At 326 minutes, subject reported that discomfort in right knee had returned; pain score of 1. At 6th-hour questioning, there was no discomfort in either ankle, but both knees still had same level of discomfort with an occasional sharp pain. His chamber mate (42-02) had also reported symptoms in right knee at 6th-hour questioning. Symptoms in both knees resolved during descent at 12.3 psia on the way to site pressure.

Diagnosis: Grade 2 Type I DCS
Treatment: None, medical observation most likely for 12 hours with follow-up consultation.

31. Summary: ID# 61-03, 29-year-old male, maximum Grade 4, first VGE at 41 minutes, first report at 83 minutes a symptom he noticed at 78 minutes, study done on n = 28, independent sample statistical design.

Procedure 7

Narrative: At 83 minutes, subject reported constant ache in joint, dull ache in left knee. Reported initial pain score of 2 on a 1–10 scale. He first noticed this symptom at 78 minutes, during last set of exercise activities, but did not interfere with his exercise activities. Pain score reported to increase to 3 by 2nd-hour questioning, at 128 minutes,; subject reported that flexing left knee at the Doppler monitoring station made dull ache worse. At 3rd-hour questioning, subject reported pain in left knee was at same level as before, a pain score of 3, but now left foot had a cramp symptom between toes and ankle. Symptom was described as "sharp;" a pain score of 2. At 220 minutes, subject reported an increase in pain score to 5 in left knee with trouble flexing the knee as required at the Doppler monitoring station. Symptom was described as still a dull ache, with no problems to continue the test or to walk to each exercise station. At 4th-hour questioning, subject reported a worse feeling in left ankle and left knee; a pain score of 6. He said that he preferred to put weight on his right leg, and that he limped a little. Pain was noticeable when he rotated the left ankle. MO decided to remove subject from the test. Initiated repressurization at 268 minutes. First VGE detected at 41 minutes, Grade 0 from left arm, Grade 3 from left leg, Grade 0 from right arm, and Grade 0 from right leg. Last VGE record at 253 minutes with Grade 0 from left arm, Grade 4 from left leg, Grade 2 from right arm, and Grade 2 from right leg. Symptoms in left knee and left ankle almost completely resolved during descent at 9.36 psia. During debrief at site pressure, subject mentioned that improvement in symptoms during repressurization was dramatic. Pain in left knee was localized beneath the patella and was at its worst at 4th-hour questioning.

Diagnosis: Grade 3 Type I DCS
Treatment: None, medical observation most likely for 12 hours with follow-up consultation.

32. Summary: ID# 13-04, 36-year-old male, maximum Grade 4, first VGE at 88 minutes, first report at 205 minutes a symptom he noticed at 180 minutes, study done on n = 28, independent sample statistical design.

Procedure 7

Narrative: At 205 minutes, subject reported constant, uncomfortable pain in left knee. Reported initial pain score of 3–4 on a 1–10 scale. He first noticed symptom at 3rd-hour questioning, but did not report it at that time. Symptom was noticed when he was lying on his back during a previous rest period. At 4th-hour questioning, subject reported pain in left knee was perhaps a little less than previously reported, was not worse with movement, and did not interfere with his exercise activities. At 242 minutes, the score decreased to 3. At 302 minutes during 5th-hour questioning, subject reported left knee pain was about gone and not continuous. His chamber mate (46-01) had reported a symptom in right knee during 5th-hour questioning. First VGE detected at 88 minutes, Grade 0 from left arm, Grade 0 from left leg, Grade 1 from right arm, and Grade 0 from right leg. Last VGE record at 347 minutes with Grade 0 from left arm, Grade 3 from left leg, Grade 2 from right arm, and Grade 0 from right leg. At 6th-hour questioning, subject reported that pain in left knee was now gone, and had been absent since last report at 5th-hour questioning. Symptoms resolved while at the test altitude of 4.3 psia prior to the repressurization to site pressure.

Diagnosis: Grade 2 Type I DCS
Treatment: None, subject was advised to stay in the quarantine trailer for 12 hours of medical observation, but did not stay. Follow-up consultation the next day.

Bends 3b: DCS Assigned at JSC

33. Summary: ID# 63-01, 23-year-old male, maximum Grade 4, first VGE at 24 minutes, first report at 120 minutes a symptom he noticed at 90 minutes, study done on n = 35, independent sample statistical design.

Procedure 8

Narrative: At 120 minutes, subject reported intermittent stiffness in right ankle. Reported initial pain score of 1 on a 1–10 scale. He noticed symptoms about 30 minutes earlier. Pain score remained constant at 1 at 89 minutes, and decreased to 0 at 178 minutes; there was no stiffness in right ankle at the 3rd- to 6th-hour questioning. First VGE detected at 24 minutes, Grade 0 from left arm, Grade 0 from left leg, Grade 0 from right arm, and Grade 1 from right leg. Last VGE record at 350 minutes with Grade 0 from left arm, Grade 0 from left leg, Grade 0 from right arm, and Grade 0 from right leg. There were no symptoms prior to descent; symptoms resolved at the test altitude of 4.3 psia. Repressurization was back to 10.2 psia.

Diagnosis: Grade 1 Type I DCS
Treatment: None, just self-monitoring most likely with follow-up consultation.

34. Summary: ID# 60-01, 23-year-old male, maximum Grade 4, first VGE at 134 minutes, first report at 180 minutes a symptom he noticed about 160 to 165 minutes earlier. Symptoms reported at 300 minutes are likely to be DCS-related, study done on n = 35, independent sample statistical design.

Procedure 8

Narrative: At 180 minutes, during 3rd-hour questioning, subject reported slight tingling in right wrist. Reported initial pain score of 1 on a 1–10 scale. He noticed pain about 160 to 165 minutes earlier, and it lasted a few minutes while pulling on the Pull Station exercise. Pain score remained constant at 1 at 180 minutes, then decreased to a pain score of 0 at 239 minutes, during 4th-hour questioning. At 5th-hour questioning, subject reported a stiff right ankle, not a soreness, that he had first noticed at the last exercise. He gave right ankle a pain score of 2 at 300 minutes. First VGE detected at 134 minutes, Grade 0 from left arm, Grade 0 from left leg, Grade 0 from right arm, and Grade 2 from right leg. Last VGE record at 350 minutes with Grade 0 from left arm, Grade 0 from left leg, Grade 0 from right arm, and Grade 3 from right leg. At 6th-hour questioning, subject reported a slight constant pain in right ankle, a little less noticeable than at 5th-hour questioning. There was no further report about right wrist. Symptoms in right ankle resolved during descent at 5.3 psia on the way to 10.2 psia. During debrief while at 10.2 psi,a subject mentioned that symptoms were best characterized as a constant awareness, not a pain.

Diagnosis: Grade 1 Type I DCS
Treatment: None, just self-monitoring most likely with follow-up consultation.

35. Summary: ID# 51-01, 26-year-old male, maximum Grade 0, first report at 240 minutes, study done on n = 35, independent sample statistical design.

Procedure 8

Narrative: At 240 minutes, during 4th-hour questioning, subject reported a little fatigue in left arm but no pain. Did not report initial pain score on the 1–10 scale. At 5th-hour questioning, he still report some fatigue in left arm and assigned a 2–3 pain score. At 352 minutes, gave a final report of fatigue in left arm bicep. Subject had no VGE during the test. Last VGE record at 341 minutes with Grade 0 from left arm, Grade 0 from left leg, Grade 0 from right arm, and Grade 0 from right leg. Symptoms of fatigue in left arm resolved during descent at 7.4 psia on the way to 10.2 psia. During debrief while at 10.2 psia, subject said that feeling of fatigue was worse in 4th-hour questioning than toward 6th-hour questioning, but cleared up on repressurization to site pressure. There were never any numbness or pins-and-needles sensations.

Diagnosis: Grade 1 Type I DCS
Treatment: None, just self-monitoring most likely with follow-up consultation.

36. Summary: ID# 47-02, 26-year-old male, maximum Grade 4, first VGE at 39 minutes, first report at 123 minutes a symptom he noticed at 113 minutes, study done on n = 35, independent sample statistical design.

Procedure 8

Narrative: At 123 minutes, subject reported ache in left knee. Reported initial pain score of 1 on a 1–10 scale. He noticed pain 10 minutes earlier at 113 minutes at the Doppler monitoring station. There was no ache while standing. Pain score remained constant a 1 at 184, 241, 300, and 360 minutes. At 2nd-hour questioning, subject reported left knee felt as though it had to be "popped" and had a dull pain. At 4th-, 5th-, and 6th-hour questioning, subject reported no change in symptoms in left knee. Pain was only noticeable at the Doppler monitoring station and only when lifting left leg. First VGE detected at 39 minutes, Grade 0 from left arm, Grade 3 from left leg, Grade 0 from right arm, and Grade 0 from right leg. Last VGE record at 358 minutes with Grade 0 from left arm, Grade 1 from left leg, Grade 0 from right arm, and Grade 0 from right leg. Symptoms in left knee resolved during descent at 5.7 psia on the way to 10.2 psia. During debrief while at 10.2 psia, subject mentioned that pain, which was more like a discomfort, was less than he experienced in a previous test (47-01) where he also reported pain in left knee.

Diagnosis: Grade 2 Type I DCS
Treatment: None, just self-monitoring most likely with follow-up consultation.

37. Summary: ID# 8-04, 28-year-old male, maximum Grade 4, first VGE at 133 minutes, first report at 169 minutes a symptom he had at 164 minutes, study done on n = 35, independent sample statistical design.

Procedure 8

Narrative: At 169 minutes, subject reported constant pain in right knee and right ankle. Reported initial pain score of 1 on a 1–10 scale. He reported that symptom was present 5 minutes earlier. At 3rd-hour questioning, reported no change in symptoms from right knee and right ankle. At 180 minutes, level was constant at 1; and at 208 minutes, level increased to 2, and was worse while moving left leg at the Doppler monitoring station. At 4th-hour questioning, pain score for right knee was 1, no mention of was made of right ankle, and a new symptom was reported in left knee at a pain score of 1. At 5th- and 6th-hour questioning, a pain score of 1 was given for right knee, right ankle, and left knee. His chamber mates (27-05 and 62-02) had also reported symptoms during this test. First VGE detected at 133 minutes, Grade 0 from left arm, Grade 0 from left leg, Grade 0 from right arm, and Grade 2 from right leg. Last VGE record at 351 minutes with Grade 0 from left arm, Grade 3 from left leg, Grade 1 from right arm, and Grade 2 from right leg. Symptoms in both knees and right ankle resolved during descent at 9.0 psia on the way to 10.2 psia.

Diagnosis: Grade 2 Type I DCS
Treatment: None, just self-monitoring most likely with follow-up consultation.

38. Summary: ID# 27-05, 40-year-old male, maximum Grade 4, first VGE at 256 minutes, first report at 334 minutes a symptom he noticed at 324 minutes, study done on n = 35, independent sample statistical design.

Procedure 8

Narrative: At 334 minutes, subject reported mild pain in right knee. Reported initial pain score of 1 on a 1–10 scale. He reported that symptom was present at 324 minutes. At 6th-hour questioning, subject reported mild sensation in right knee, mostly present at the Doppler monitoring station when right leg was moved horizontally, and also noticed the sensation occasionally at other stations. His chamber mates (8-04 and 62-02) had also reported symptoms during this test. This subject had reported a symptom in the right knee at 76 minutes in a previous test (27-01). First VGE detected at 256 minutes, Grade 0 from left arm, Grade 0 from left leg, Grade 0 from right arm, and Grade 0 from right leg. Last VGE record at 348 minutes with Grade 1 from left arm, Grade 1 from left leg, Grade 1 from right arm, and Grade 4 from right leg. Symptoms resolved prior to descent, while at the test altitude of 4.3 psia. Repressurization was back to 10.2 psia.

Diagnosis: Grade 1 Type I DCS
Treatment: None, just self-monitoring most likely with follow-up consultation.

39. Summary: ID# 44-01, 36-year-old male, maximum Grade 4, first VGE at 107 minutes, first report at 225 minutes a symptom he noticed at about 221 minutes, study done on n = 35, independent sample statistical design.

Procedure 8

Narrative: At 225 minutes, subject reported pain around the front in right ankle. Reported initial pain score of 8–9 on a 1–10 scale for a few seconds, and 3–4 for about 45 seconds; but at this time pain was gone. Pain score fluctuated during remainder of test. He first noticed right ankle symptom moments before, at about the time of last Doppler measurement at 221 minutes. For completeness, subject had initially reported tiredness in right wrist at 1st-hour questioning, and tiredness in right forearm at 2nd-hour questioning, with no tiredness in right wrist. At 3rd-hour questioning, he reported tiredness in right wrist, along back of right wrist, and in right forearm. At this time (180 minutes), he mentioned a momentary sharp pain on back of right wrist. At 4th-hour questioning, he reported that right ankle had no symptoms, but there was general tiredness in right knee at a pain score of 2. Pain was localized in front of right knee, below patella, but did not interfere with performance of the exercises. At 255 minutes, subject reported pain in right knee at a pain score of 2–3. At 268 minutes, subject reported right wrist and right knee hurt when he walked in the chamber but did not hurt when he stood still. At 273 minutes, there was no pain while motionless on the Doppler monitoring cot, but there was a noticeable discomfort in right knee and right ankle when right leg was moved from a horizontal position. He volunteered a pain score of 4. At 5th-hour questioning, pain in right knee was still present and given a pain score of 4 when walking; it did not interfere with walking. Pain was localized about 2 inches below patella. At 331 minute, subject reported slight discomfort in right knee and right ankle while sitting, a mild pain in these locations while walking, and overall less pain than previous reports. At 6th-hour questioning, subject reported no sharp pain anymore in right knee or right ankle, and not made worse by movement now; a pain score of 1 by inference. First VGE detected at 107 minutes, Grade 0 from left arm, Grade 0 from left leg, Grade 0 from right arm, and Grade 2 from right leg. Last VGE record at 369 minutes with Grade 0 from left arm, Grade 0 from left leg, Grade 1 from right arm, and Grade 2 from right leg. Symptoms in right knee and right ankle resolved during descent at 10.3 psia on the way to 10.2 psia.

Diagnosis: Grade 2 Type I DCS
Treatment: None, just self-monitoring most likely with follow-up consultation.

40. Summary: ID# 62-02, 32-year-old male, maximum Grade 1, first VGE at 103 minutes, first report at 120 minutes a symptom he noticed at 105 minutes, study done on n = 35, independent sample statistical design.

Procedure 8

Narrative: At 120 minutes, during 2nd-hour questioning, subject reported fullness in left knee. Reported initial pain score of 1 - 2 on a 1–10 scale. He noticed symptom earlier at 105 minutes. At 3rd-hour questioning, subject reported that left knee was better now; no pain score reported. At 4th-, 5th- and 6th-hour questioning, there were no problem with left knee. His chamber mates (8-04 and 27-05) had also reported symptoms during test. First VGE detected at 103 minutes,

Grade 0 from left arm, Grade 1 from left leg, Grade 0 from right arm, and Grade 0 from right leg. Last VGE record at 343 minutes with Grade 0 from left arm, Grade 0 from left leg, Grade 0 from right arm, and Grade 0 from right leg. VGE grade never exceeded 1, but was detected from left leg. There were no symptoms prior to descent; symptoms resolved at the test altitude of 4.3 psia. Repressurization was back to 10.2 psia.

Diagnosis: Grade 1 Type I DCS
Treatment: None, just self-monitoring most likely with follow-up consultation.

Bends 3c: DCS Assigned at JSC

41. Summary: ID# 44-03, 36-year-old male, maximum Grade 2, first VGE at 77 minutes, first report at 105 minutes, study done on n = 14, independent sample statistical design.

Procedure 9

Narrative: At 105 minutes, subject reported discomfort in right ankle. At 2nd-hour questioning, subject reported steady discomfort in right ankle at initial pain score of less than 1 on a 1–10 scale. Pain score increased to 2 at 145 minutes; transient right hip discomfort had gone away. Pain score in right ankle then decreased to 1 at 157 and 178 minutes. At 4th-hour questioning, he reported a barely perceptible discomfort in right knee, right ankle had a continuous discomfort. Subject had reported pain symptoms in right ankle at 225 minutes during a previous exposure (44-01). First VGE detected at 77 minutes, Grade 0 from left arm, Grade 0 from left leg, Grade 1 from right arm, and Grade 0 from right leg. Last VGE record at 355 minutes with Grade 0 from left arm, Grade 0 from left leg, Grade 0 from right arm, and Grade 0 from right leg. At 5th-hour questioning, subject reported discomfort in right ankle had increased to a pain score of 2 when ankle was rotated, but discomfort did not interfere with his exercise activities. At 6th-hour questioning, pain score for right ankle had decreased to 1. Symptoms in right ankle resolved during descent to site pressure at 9.5 psia.

Diagnosis: Grade 2 Type I DCS
Treatment: None, medical observation most likely for 12 hours with follow-up consultation.

42. Summary: ID# 48-03, 36-year-old male, maximum Grade 3, first VGE at 172 minutes, first report at 300 minutes a symptom he noticed at 296 minutes, study done on n = 14, independent sample statistical design.

Procedure 9

Narrative: At 300 minutes, during 5th-hour questioning, subject reported a dull aching pain in right knee. He noticed symptom at about 296 minutes while at the Doppler monitoring station. Reported initial pain score of 3–4 on a 1–10 scale, based on his recollection of first symptom. Now at 300 minutes, pain score decreased to 1. Right knee was more of a problem whenever he put weight on it. At 6th-hour questioning, he reported that right knee pain had been gone since shortly after 5th-hour questioning. His exposure to 4.3 psia the previous day (48-02) produced

a symptom in right shoulder after the 5th hour at 4.3 psia. First VGE detected at 172 minutes, Grade 0 from left arm, Grade 0 from left leg, Grade 0 from right arm, and Grade 2 from right leg. Last VGE record at 352 minutes with Grade 0 from left arm, Grade 0 from left leg, Grade 0 from right arm, and Grade 0 from right leg. There were no symptoms prior to descent; symptoms resolved at the test altitude of 4.3 psia. During debrief at site pressure, subject mentioned that pain in right knee was localized below the patella and was intermittent. He also mentioned a little ill-defined pain in his right shoulder.

Diagnosis: Grade 2 Type I DCS
Treatment: None, medical observation most likely for 12 hours with follow-up consultation.

43. Summary: ID# 10-07, 45-year-old male, maximum Grade 3, first VGE at 221 minutes, first report at 203 minutes a symptom he noticed at 201 minutes, study done on n = 14, independent sample statistical design.

Procedure 9

Narrative: At 203 minutes, subject reported intermittent pain in left ankle. Reported initial pain score of 2–3 on a 1–10 scale. He noticed symptom at last exercise station, at about 201 minutes. At 4th-hour questioning, he reported pain in left ankle at a decreased pain score of 2; pain was associated with movement of ankle joint, was worse if he rose on tiptoes, and was least when sitting with weight off his feet. At 5th-hour questioning, left ankle discomfort was intermittent and subsided to a pain score of 1. At 6th-hour questioning, left ankle discomfort was still intermittent and subsided to a pain score of less than 1. First VGE detected at 221 minutes, Grade 0 from left arm, Grade 2 from left leg, Grade 0 from right arm, and Grade 0 from right leg. Last VGE record at 349 minutes with Grade 0 from left arm, Grade 0 from left leg, Grade 0 from right arm, and Grade 0 from right leg. Symptoms in left ankle resolved during descent at 6.3 psia. During debrief at site pressure, subject mentioned pain in left ankle was directly on the ankle, and on both sides.

Diagnosis: Grade 2 Type I DCS
Treatment: None, medical observation most likely for 12 hours with follow-up consultation.

Bends 3d: DCS Assigned at JSC

44. Summary: ID# 60-03, 23-year-old male, maximum Grade 4, first VGE at 105 minutes, first report at 239 minutes, study done on n = 12, independent sample statistical design.

Procedure 10

Narrative: Subject had reported symptoms at 1 hour in left shoulder and left elbow the day before while at 4.3 psia. PI was not convinced that these were symptoms of DCS. During the morning prior to 2nd test to 4.3 psia, subject reported to PI that he had no aches or pains in the shoulder while at 10.2 psia for the evening. But when he awoke, he had a slight numbness in a leg that lasted 10 minutes until he moved around. Subject was clear to perform the test. At 239

minutes, subject reported slight discomfort in left shoulder. Reported initial pain score of 3 on a 1–10 scale while exercising the limb; score decreased to 1 when not exercising the limb. Subject reported that pain was similar to that he experienced during the previous test, 1 day earlier. At 5th-hour questioning, subject still reported slight pain in left shoulder, with a pain score of 1. At 335 minutes, subject reported slight stiffness in right ankle that he noticed moments before while walking between exercise stations. He assigned it a pain score of 1–2. At 6th-hour questioning, subject reported slight pain in left shoulder, at a pain score of 3 with right ankle assigned a score of 4. Subject had previously reported (60-01) a symptom in right ankle at 5th-hour questioning of the test, but this was in a test that was conducted about 2 weeks earlier. First VGE detected at 105 minutes, Grade 0 from left arm, Grade 0 from left leg, Grade 0 from right arm, and Grade 3 from right leg. Last VGE record at 353 minutes with Grade 0 from left arm, Grade 0 from left leg, Grade 0 from right arm, and Grade 2 from right leg. Symptoms in right ankle resolved during descent at 9.5 psia, and symptoms in left shoulder were reported to feel better at 13 psia. During debrief at site pressure, the PI was not as clear that subject's left shoulder was a DCS problem, but was clear that right ankle pain was a clear DCS problem.

Diagnosis: Grade 2 Type I DCS
Treatment: None, medical observation most likely for 12 hours with follow-up consultation.

45. Summary: ID# 42-05, 28-year-old male, maximum Grade 2, first VGE at 149 minutes, first report at 241 a symptom he noticed at 216 minutes, study done on n = 12, independent sample statistical design.

Procedure 10

Narrative: Subject had no reported aches or pains during exposure to 4.3 psia the previous day. At 241 minutes, during 4th-hour questioning, subject reported ache in right ankle. Reported initial pain score of 3 on a 1–10 scale. He had first noticed symptom 25 minutes earlier; but ache did not interfere with exercise activities. First VGE detected at 149 minutes, Grade 0 from left arm, Grade 0 from left leg, Grade 1 from right arm, and Grade 2 from right leg. Last VGE record at 347 minutes with Grade 0 from left arm, Grade 0 from left leg, Grade 0 from right arm, and Grade 0 from right leg. At 5th-hour questioning, subject reported pain in right ankle had subsided to a pain score of 2, but was still a continuous pain. It felt worse when putting his weight on right ankle. He felt 2 distinct pains in right ankle while lying down: one on top of the ankle and one under the ankle. Pain on top of the ankle was worse when lying down. At 6th-hour questioning, subject reported pain in right ankle only hurt when he put weight on it, but still about a pain score of 2 when weight was put on it. Symptoms in right ankle resolved during descent at 7.3 psia. During debrief at site pressure, subject localized right ankle pain to the muscle or tendons around the joint, and not to pain within the joint.

Diagnosis: Grade 2 Type I DCS
Treatment: None, medical observation most likely for 12 hours with follow-up consultation.

Bends 4a: DCS Assigned at JSC

46. Summary: ID# 64-01, 29-year-old male, maximum Grade 4, first VGE at 16 minutes, first report at 60 minutes a symptom he noticed at 24 minutes, study done on n = 12, independent sample statistical design.

Procedure 11

Narrative: At 1st-hour questioning, subject reported that about 35 minutes earlier (24 minutes elapsed time) he experienced a slight dull ache in left elbow. At this time while at the Doppler monitoring station, he noticed a transient twinge in left knee and persistent twinge in right knee. Reported initial pain score of 1 on a 1–10 scale for left elbow and left knee, and a score of 3 for right knee. None of the 3 symptoms interfered with exercise activities. Pain score decreased to 1 at 119 minutes, and then decreased to 0 at 176 minutes. At 2nd-hour questioning, subject reported no noticeable aches or pain sensations at all from right knee, but characterized symptoms in left elbow and left knee as a very slight awareness. First VGE detected at 16 minutes, Grade 3 from left arm, Grade 3 from left leg, Grade 0 from right arm, and Grade 2 from right leg. Last VGE record at 162 minutes with Grade 2 from left arm, Grade 4 from left leg, Grade 1 from right arm, and Grade 4 from right leg. At 3rd-hour questioning, there were no symptoms to report, and the chamber was recompressed to 10.2 psia for a lunch break prior to second decompression of the day back to 4.3 psia. There were no symptoms prior to descent to 10.2 psia; symptoms resolved at the test altitude of 4.3 psia. Just after arriving at 10.2 psia for a lunch break, a Doppler reading was taken and subject had no VGE. Subject had no VGE on the second 3-hour exposure to 4.3 psia after the lunch break.

Diagnosis: Grade 2 Type I DCS
Treatment: None, just self-monitoring most likely with follow-up consultation.

Bends 5a: DCS Assigned at JSC

47. Summary: ID# 91-01, 51-year-old female, maximum Grade 4, first VGE at 128 minutes, first report at 180 minutes a symptom she noticed at 165 minutes, study done on n = 38, independent sample statistical design.

Procedure 12

Narrative: At 180 minutes, subject reported that right ankle hurt a little. Did not report initial pain score on the 1–10 scale. Ache was first noticed at the Doppler monitoring station, as a little twinge that came and went. Symptom did not interfere with exercise activities by 3rd hour. She mentioned that symptom had appeared about 15 minutes earlier (165 minutes); her only other report, at 2nd-hour questioning, was a transient cramp in her left side during previous exercise activity. At 180, 240, 300, and 360 minutes, level remained constant at 1. At 4th-hour questioning, she reported there was still an intermittent twinge in her right ankle, no better or worse than before, and a little more pronounced when she lay down at the Doppler monitoring station. At the 5th-hour questioning, she reported that right ankle still felt funny when rotating the joint. At

6th-hour questioning, she reported a slight discomfort in right ankle, but not as bad as previous reports. First VGE detected at 128 minutes, Grade 0 from left arm, Grade 0 from left leg, Grade 0 from right arm, and Grade 3 from right leg. Last VGE record at 344 minutes with Grade 0 from left arm, Grade 0 from left leg, Grade 0 from right arm, and Grade 1 from right leg. Subject had a right ear block during descent that diverted from detailed monitoring of any change in symptoms in right ankle. There were no symptoms in right ankle at site pressure. During debrief, she mentioned that mild pain had bothered her for about 2 hours, but gradually became a very mild sensation by the end of the test.

Diagnosis: Grade 1 Type I DCS
Treatment: None, just self-monitoring most likely with follow-up consultation.

48. Summary: ID# 92-01, 45-year-old female, maximum Grade 3, first VGE at 277 minutes, first report at 300 minutes a symptom she noticed at 292 minutes, study done on n = 38, independent sample statistical design.

Procedure 12

Narrative: At 300 minutes, during 5th-hour questioning, subject reported that right arm had experienced a hurtful sensation, in both the right wrist and right upper arm. Did not report initial pain score on the 1–10 scale. She noticed symptoms at about 292 minutes while at the previous Doppler monitoring station. At 300 minutes, symptom in right arm was all but gone. Feeling was slight in right wrist, arm, and upper arm. At 312 minutes, she felt a sensation in right arm while she was on the cot used for Doppler monitoring. Bubbles were not detected with confidence until 312 minutes into the test. There were Grade 2 and 3 VGE from the left and right leg with a single Grade 1 VGE from the right arm at 312 minutes. She reported no symptoms at 328 minutes or at 360 minutes. First VGE detected at 277 minutes, Grade 0 from left arm, Grade 2 from left leg, Grade 0 from right arm, and Grade 0 from right leg. Last VGE record at 348 minutes with Grade 0 from left arm, Grade 0 from left leg, Grade 0 from right arm, and Grade 0 from right leg. There were no symptoms prior to descent; symptoms resolved at the test altitude of 4.3 psia. During debrief, she mentioned that there was pain also in her right shoulder, and all symptoms in the right arm had appeared during the Doppler monitoring period just prior to and just after the 4th hour of the test.

Diagnosis: Grade 2 Type I DCS
Treatment: None, just self-monitoring most likely with follow-up consultation.

49. Summary: ID# 96-01, 27-year-old male, maximum Grade 4, first VGE at 39 minutes, first report at 60 minutes a symptom he noticed minutes earlier, study done on n = 38, independent sample statistical design.

Procedure 12

Narrative: At 60 minutes, subject reported pain in left ankle. Did not report initial pain score on the 1–10 scale. He reported that pain was first noticed during the previous Doppler monitor-

ing, and ached only when the joint was rotated. At 80 minutes, he reported that pain had spread to left knee and felt "like when you need to pop a knuckle," but it did not interfere with exercise activities. At 2nd-hour questioning, subject reported that left ankle pain was only noticeable when moving the joint, and left knee pain had not changed in intensity or character since the last report at 80 minutes. At 3rd-hour questioning, the left ankle felt okay, but there was still pain in the left knee especially during the Doppler monitoring. He reported a new pain in the right ankle, which appeared about 30 minutes earlier. Pain score remained constant at 1 at 80, 120, 150, 180, 199, 219, and 240 minutes, but increased to 9–10 at 300 and 360 minutes. At 219 minutes, subject reported that right knee pain was noticeable while just quietly sitting, but still not severe enough to interfere with exercise activities. At 4th-hour questioning, pain in left ankle was the same, a decrease of pain in the left knee, right ankle, and right knee. At 5th-hour questioning, subject reported that left knee, left ankle, right knee, and right ankle were the same as before. However, at this time subject volunteered a pain score of 9–10, but the logbook does not specify the location for these scores. At 6th-hour questioning, subject reported left leg had less intense pain than right leg. First VGE detected at 39 minutes, Grade 0 from left arm, Grade 2 from left leg, Grade 2 from right arm, and Grade 0 from right leg. Last VGE record at 356 minutes with Grade 0 from left arm, Grade 1 from left leg, Grade 0 from right arm, and Grade 3 from right leg. Symptoms in both legs (knees and ankles) resolved during descent at 5.0 psia at the same time. During debrief, subject volunteered that left ankle had become sore on movement about 30 minutes into the test, and pain had spread to left knee after about 10–15 minutes. Pain had intensified over the next hour. Then about 3 hours into the test, the right ankle and right knee followed the same pattern of symptom onset. There were periods where symptoms were more noticeable, especially during the Doppler monitoring periods or when getting up from a seated or lying position.

Diagnosis: Grade 2 Type I DCS
Treatment: None, just self-monitoring most likely with follow-up consultation.

50. Summary: ID# 97-01, 36-year-old female, maximum Grade 4, first VGE at 91 minutes, first report at 112 minutes a symptom she noticed at 104 minutes, study done on n = 38, independent sample statistical design.

Procedure 12

Narrative: At 112 minutes, subject reported dull ache in right knee. Reported initial pain score of 1 on a 1–10 scale. Subject reported that she first noticed ache at about 104 minutes after completing the Doppler monitoring, and it did not interfere with her exercise activity. Pain score increased to 2 at 120 and 132 minutes, and then increased to 4–5 at 149 minutes followed by a decrease to 3 at 180 minutes. At 120 minutes, during 2nd-hour questioning, she said that ache in right knee was just a little worse than before. It was a continuous ache that did not interfere with her performance. At 132 minutes, subject reported that right knee was getting tender to walk on, and she needed to limp to get to the different exercise stations. At 144 minutes, subject reported a dull sensation in right hip that felt like the sensation she first had in right knee, but at a lower intensity than was in right knee at that time. At 149 minutes, subject reported that right ankle was now hurting, but she was still able to walk from station to station. At 3rd-hour questioning, she reported that an ache was still present in right knee and right ankle, but pain in right hip was not as bad as before. A pain score of 2.5 was provided, but it was unclear if this was for one or all

the locations. An earlier report at 155 minutes of pain in the left ankle of the DT had increased, and the DT's right ankle had become involved at 192 minutes. At 194 minutes both knees, and especially the right knee, of the DT became painful enough to cause the early termination of the test. First VGE for subject was detected at 91 minutes, Grade 0 from left arm, Grade 0 from left leg, Grade 0 from right arm, and Grade 2 from right leg. Last VGE record at 176 minutes with Grade 0 from left arm, Grade 0 from left leg, Grade 2 from right arm, and Grade 3 from right leg. Symptoms in right knee, right ankle, and right hip for subject resolved dramatically during descent at 5.9 psia. During debrief, subject mentioned that pain in right ankle went from a pain score of 6 to a pain score of about 2 toward the end of the test.

Diagnosis: Grade 2 Type I DCS
Treatment: None, just self-monitoring most likely with follow-up consultation.

Bends 6: DCS Assigned at JSC

51. Summary: ID# 109-01, 31-year-old male, maximum Grade 3, first VGE at 98 minutes, first report at 182 minutes a symptom he noticed at 152 minutes, study done on n = 29, independent sample statistical design.

Procedure 13

Narrative: At 182 minutes, at the 3rd-hour questioning, subject reported a dull pain localized in the belly of left bicep, but no joint pain. Did not report initial pain score on the 1–10 scale. During debrief, he mentioned that symptom had appeared about 30 minutes earlier. At 4th-hour questioning, subject reported that he still had a dull continuous pain in his left arm. At 180, 240, 300, and 360 minutes, the pain score remained constant at 1. At 240 minutes, subject reported there was still a dull pain in left arm. At 300 minutes, pain was receding; by 360 minutes, there was still some pain in left arm. At 6th-hour questioning, he also volunteered that he experienced a slight ache in right ankle when he walked on right leg. But ache was gone when he sat quietly (he later recalled that he had symptoms in right ankle while resting just prior to repressurization). First VGE detected at 98 minutes, Grade 0 from left arm, Grade 0 from left leg, Grade 0 from right arm, and Grade 1 from right leg. Last VGE record at 356 minutes with Grade 0 from left arm, Grade 0 from left leg, Grade 0 from right arm, and Grade 0 from right leg. Symptoms in left arm and right ankle did not clear during descent, but were resolved at site pressure. During debrief, he reported that he first noticed pain in left arm as a dull sensation about 30 minutes before reporting it. This dull pain was in the tricep muscle (bicep was mentioned in another section of the logbook, but it appears to have been in the tricep), and was a continuous pain. Subject was asked to turn the ergometer at site pressure and to walk about to see if any symptoms were present in the right ankle or left arm. Subject reported that the symptoms were amazingly diminished, and no pain was present in any limb by the end of debrief. Subject was contacted 48 hour later by the PI. Subject mentioned that he had twisted his right ankle 4 or 5 times in the past 4 or 5 years, and that he did recall having symptoms in his right ankle just prior to repressurization to site pressure at the end of the 6-hour test.

Diagnosis: Grade 1 Type I DCS
Treatment: None, just self-monitoring most likely with follow-up consultation.

Bends 7 (high exercise): DCS Assigned at JSC

52. Summary: ID# 123-01, 28-year-old male, maximum Grade 4, first VGE at 61 minutes, first report at 90 minutes, study done on n = 11, crossover dependent sample statistical design.

Procedure 14

Narrative: At 90 minutes, subject reported a cramp in lower right leg (calf). Did not report initial pain score on a 1–10 scale. Still had cramp at 94 minutes, but did not have it during practice exercise at site pressure. There was no pain score report at 121, 161, or 172 minutes into the test. At 100 minutes, the cramp had diminished. At 120 minutes, he reported a slight headache in frontal area and pain in bell of muscle of right calf; the pain was present most of the time now. At 127 minutes, the PI noted that what started out as a cramp was now a mild throbbing that had diminished in discomfort. At 164 minutes, he reported pain in right knee, shooting and throbbing, "pretty good jab of pain." When he had right knee up, it hurt; when it was extended, the pain diminished. Pain was in back of, in front of, and all around knee, but did not interfere with performance. First VGE detected at 61 minutes, Grade 0 from left arm, Grade 4 from left leg, Grade 1 from right arm, and Grade 4 from right leg. Last VGE record at 161 minutes with Grade 0 from left arm, Grade 3 from left leg, Grade 0 from right arm, and Grade 3 from right leg. At 172 minutes, subject reported dizziness and sudden onset of "wobbly" and then blurred vision. Test was immediately aborted. Symptoms were clearing within 2 minutes of repressurization to site pressure. Vision cleared at 10.1 psia, headache cleared at 10.9 psia, and knee pain resolved just prior to return to site pressure (13.7 to 14.7 psia). At debrief, he described last symptom as dizziness associated with at first a "wobbly" vision that he found hard to describe, then a blurring of vision. There were no signs of posttest neurological deficit.

Diagnosis: Type II DCS with Grade 3 Type I DCS
Treatment: Two-hour GLO, 12-hour medical observation, then released from study with follow-up consultation. Subject did have a PFO, with positive indication at rest. Dr. Meehan made additional opthalamic observations with a fundus camera immediately after the return to site pressure, but comments in the logbook were illegible.

53. Summary: ID# 121-01, 30-year-old male, maximum Grade 4, first VGE at 49 minutes, first report at 75 minutes, study done on n = 11, crossover dependent sample statistical design.

Procedure 14

Narrative: At 75 minutes, subject reported continuous pain in left-hand ring finger, at joint just behind fingernail. Did not report initial pain score on the 1–10 scale. At 83 minutes and 96 minutes, pain in left-hand ring finger was almost gone. By 102 minutes, there was no pain in left-hand ring finger. Pain score was not reported at 155 or 160 minutes into test. At 159 minutes, he reported pain in right knee, just below the patella. Subject reported that he noticed the sharp pain

about 30 seconds before reporting it. It was determined that although it caused repeated pain on the row machine, this did not interfere with performance. First VGE detected at 49 minutes, Grade 0 from left arm, Grade 1 from left leg, Grade 0 from right arm, and Grade 0 from right leg. Last VGE record at 164 minutes with Grade 2 from left arm, Grade 2 from left leg, Grade 2 from right arm, and Grade 4 from right leg. At 172 minutes, he reported pain behind right eye; a throbbing headache localized behind right eye felt like a sinus headache. Test was aborted, and recompression to site pressure began approximately 8 minutes from the report of pain behind the right eye. Headache was diminishing with increased ambient pressure; knee pain was greatly reduced but still some awareness at site pressure. Ophthalmologic examination at site pressure revealed some sheathing of vessels and some change in the ground. While waiting for the chamber to be readied, the headache did not resolve and may have increased its focal area and intensity. Both headache and residual knee pain were resolved during the treatment. Ophthalmologic signs decreased during treatment. At no time did subject have visual symptoms.

Diagnosis: Type II DCS and Grade 2 Type I DCS
Treatment: One-hour GLO prior to USN TT VI, medical observation for 12 hours with follow-up consultation over the next several days. A final ophthalmologic exam was negative. Did not have a detectable PFO.

Test Director's/Principal Investigators Special Report on Bends VII Test 11

Eleventh test of the Bends VII Test Series was conducted on 1/13/89. The test subjects are designated at Subject #1 (122-02), who was conducting the low metabolic rate profile and Test Subject #2 (121-01), who was conducting the high metabolic rate profile. The DT was JC, the Test Director was JW, the Test Investigator was Dr. KV and the test Surgeon was Dr. PS. Each of the test subjects had already completed one of the paired tests called for in the test series plan. Venous bubbles had been detected on both subjects during their previous run. Test subject #1 had experienced no symptoms during his prior high metabolic rate run. Test subject #2 had experienced simple limb bends in his left knee in the conduct of his low metabolic rate test. This symptom was judged to be Grade 2 limb bends and did not result in an early termination of that test. The symptom was resolved upon return to site pressure at the end of the test. Subject was observed for 12 hours and released without further symptoms. The test series protocol called for each of the test subjects to have a fundus camera measurement after one of their 2 test runs. Subject #1 had not had the measurement on his previous run and so was scheduled to have it on this run. Subject #2 had this measurement on his previous run and was not s cheduled to have the measurement on this run.

The test was begun with the start of ascent to 10,000 feet at 9:21. The start of ascent to 21,000 feet, the test altitude, was at 9:24. The test altitude, 21,000 feet was reached at 9:28 and the elapsed time clock was started at 0:00 at this same time. At this time subjects were asked the baseline question about any pain or discomfort. Subject #2 stated that he had measles shot about four days ago and that his right deltoid was a little sore. He reported that he had no other aches or pains. Subject #1 reported no ache or pain.

Subjects then began their test exercises that they were to sustain for the three hours and 16 minutes of the planned test duration. After 1 hour, in response to questioning, subject #1 reported everything was fine except for a dry mouth. Subject #2 reported he had no aches or pains other than the right shoulder where the soreness was less noticeable than originally. At an elapsed time of 1 hour and 15 minutes, subject #2 reported pain in the left fourth finger, left hand next to the little finger. This was a continuous pain in the knuckle, first joint right behind the fingernail. This pain was not interfering with performance and the test continued. At an elapsed time of 1 hour and 23 minutes crewman #2 reported that the pain in the finger was almost gone. At an elapsed time of 1 hour and 24 minutes subject #l reported a sharp momentary pain in the right elbow that was then continuous at a lower level that did not interfere with performance. At an elapsed time of 1 hour and 36 minutes both subjects were questioned about their symptoms. Subject #2 reported that his finger pain was much better, almost gone. Subject #1 reported that his elbow was still a little painful but not like it was on the rowing machine, where he first reported the symptom. At an elapsed time of 1 hour and 42 minutes subject #2 was questioned and said he had no pain in his finger. At an elapsed

time of 1 hour and 46 minutes Subject #1 reported that the pain in the elbow was just about cleared up. This was immediately after working on the rowing machine where the symptom was first reported. At about this time there was an error in the exercise routine that resulted in subject #2 working at the peak exercise rate of 2,000 Btu/hour for 20 minutes rather than the planned 16 minutes. So four additional minutes of the subsequent work rate, which should have been at the 1440 Btu / hour rate, was at 2,000 Btu/hour.

At the end of the second hour, after all the high exercise in the high exercise protocol was completed, in response to the hourly questions, Subject #1 stated that his right shoulder and his right elbow were a little sore, but nothing like at the time it first appeared on the rowing machine. This was the first time subject had mentioned his shoulder. He was asked about this and replied that when he first described the elbow pain, the shoulder did not hurt and now it does but that it could be due to his body position during the Doppler monitoring (on his left side) which is very uncomfortable. The sensations are separate and distinct, and they are continuous. They did not interfere with performance. Subject #2 reported no symptoms. He was asked about his finger and reported that the previous pain in the finger was completely gone.

The test was continued into the third hour according to protocol. In chamber blood draws were done in the first 30 minutes of this hour so there is some reduction in the work activity during this period. At an elapsed time of 2 hour and 39 minutes Subject #2 reported that he had a pain originating right below the kneecap of the right knee and that he stated having sharp pains thereafter. He had this pain for about 30 seconds before contacting us. The subject was stopped in his exercise sequence while he was being questioned. The Investigator and the Surgeon asked subject questions to determine if the symptoms were Grade 2 or Grade 3 symptoms interfering with performance. Subject said that he could continue without much trouble but with some pain. At this point the scheduled rowing activity was completed and subject was asked to move to the next station, which was the Doppler station he did so without limping. It was determined that the symptoms were Grade 2, and the test was continued. At an elapsed time of 2 hour and 52 minutes Subject #2 reported pain behind the right eye. Subject was seated and questioned by the test Surgeon. He reported a throbbing headache behind the eye, more specifically behind the right eye. At one point he said it feels like a sinus headache. At 3 hour elapsed time the test was aborted. At that time subject #1 reported no pain anywhere even when he moved his right elbow and shoulder. Subject #2 had some pain in the right knee but only when he moves it around. He still had the headache. During repress to site pressure at 10,000 feet subject #2 reported no change in symptoms. At 5,000 feet he reported that the headache was dispersing, not as bad. At site pressure subject #2 reported that he felt pretty good, still some headache, leg pain none, hardly at all. Ophthalmologic examination revealed some sheathing around major vessels and some change in color of the ground. The decision was made to treat with a table 6 treatment. Subject #2 was held in the altitude chamber on O_2 until the hyperbaric chamber was ready. Altitude chamber reached site pressure at an elapsed time of 3 hour and 4 minutes, a clock time of about 12:28. At 12:37 a posttest Doppler on subject #2 showed he still had some bubbles on movement of the right leg. Subject was transported to the hyperbaric chamber at 1:34 and treatment was started at about 1:42. Details of the treatment are reported in the outside MO report of the treatment. Subject had both CNS and limb bends symptoms at the beginning of the treatment and the symptoms disappeared during the 60-feet portion of the treatment table. The ophthalmologic signs also decreased during the treatment. All signs and symptoms were gone at the completion of the treatment. Fundus camera photographs of the eyes were taken that evening. Subject was observed for the next 12 hours without incident and follow-up was continued for the next several days. A visual field mapping procedure is scheduled with a local ophthalmologist on 1/24/89. At no time has subject had any visual symptoms, and has no residual symptoms of any kind.

54. Summary: ID# 120-01, 23-year-old male, maximum Grade 4, first VGE at 81 minutes, first report at 78 minutes, study done on n = 11, crossover dependent sample statistical design.

Procedure 14

Narrative: At 78 minutes, subject reported slight pain under patella of left knee. Reported initial pain score of 1 on a 1–10 scale. At 93 minutes, subject reported that pain had increased to a 2–3, and was constant. At 103 minutes, pain was described as located in the front and back of left knee, was constant, and had a pain score of 3. At 2nd-hour questioning, subject reported that

pain in left knee was spreading down left leg, and that both wrists had a pain score of 1 on flexing the wrists. At 145 minutes, subject reported that left knee pain had somewhat subsided. At 3rd-hour questioning, subject reported no pain in the wrists, and left knee pain was still at a pain score of 3. First VGE detected at 81 minutes, Grade 0 from left arm, Grade 1 from left leg, Grade 0 from right arm, and Grade 1 from right leg. Last VGE record at 192 minutes with Grade 0 from left arm, Grade 3 from left leg, Grade 0 from right arm, and Grade 2 from right leg. Symptoms in left knee resolved during descent at 7.65 psia.

Diagnosis: Grade 2 Type I DCS
Treatment: One-hour GLO, under medical monitoring for 12 hours. Posttest GLO was extended 10 minutes due to complaint of chest tightness after the fundus camera pictures of the eyes were completed. Follow-up consultation the next day.

55. Summary: ID# 117-01, 26-year-old male, maximum Grade 4, first VGE at 49 minutes, first report at 169 minutes a symptom he noticed minutes earlier, study done on n = 11, crossover dependent sample statistical design.

Procedure 14

Narrative: At 169 minutes, subject reported a dull ache in left knee that was noticed during earlier exercise period and was intermittent while pushing on the joint during exercise. Did not report initial pain score on the 1–10 scale. Ache was not present at the time of the report at 169 minutes. At 175 minutes, subject reported that there was a dull ache in left knee when he lifted his left leg off the floor. At 3rd-hour questioning, subject reported that left knee had a dull but clear low level of pain that did not interfere with any activities, and that knee felt like it was over-extended. Pain score was not reported at 181 minutes into test. First VGE detected at 49 minutes, Grade 0 from left arm, Grade 2 from left leg, Grade 0 from right arm, and Grade 0 from right leg. Last VGE record at 193 minutes with Grade 0 from left arm, Grade 32from left leg, Grade 0 from right arm, and Grade 0 from right leg. At 185 minutes, subject reported no symptoms in left knee using the row machine; but at 200 minutes on the row machine, there was a symptom, but not on standing. It is not clear why the test was extended by approximately 24 minutes, but recompression began at 204 minutes with no report of left knee symptoms then. Subject did not report if there was a change in left knee symptoms during descent.

Diagnosis: Grade 2 Type I DCS
Treatment: One-hour GLO with follow-up consultation.

Bends 7 (low exercise): DCS Assigned at JSC

56. Summary: ID# 121-02, 30-year-old male, maximum Grade 4, first VGE at 65 minutes, first report at 119 minutes a symptom he noticed at about 109 minutes, study done on n = 11, crossover dependent sample statistical design.

Procedure 15

Narrative: At 119 minutes, subject reported ache in left knee, left ankle, and right shoulder. Did not report initial pain score on the 1–10 scale. Subject reported that ache in left knee was noticed about 10 minutes earlier, was hurting more during the row machine exercise, and was now continuous. Left ankle ache was noticed only on the row machine, with right shoulder ache occurring only once or twice during previous exercise. Pain score was not reported at 178 or 194 minutes into test. First VGE detected at 65 minutes, Grade 2 from left arm, Grade 3 from left leg, Grade 2 from right arm, and Grade 0 from right leg. Last VGE record at 185 minutes with Grade 2 from left arm, Grade 4 from left leg, Grade 1 from right arm, and Grade 4 from right leg. At 3rd-hour questioning, subject reported a little discomfort in left knee; discomfort had not changed from previous reports. Left ankle and right shoulder pain had gone by the end of the test. Subject reported that he still felt something in his left knee during descent, but that knee was a lot better. During debrief, subject reported that there was still an awareness in left knee, but not pain. There was a discussion about pretest symptoms in the left knee that may have influenced the incomplete posttest response to recompression to site pressure. There were no symptoms in left knee at the conclusion of the posttest period of GLO.

Diagnosis: Grade 2 Type I DCS
Treatment: One-hour GLO with follow-up consultation.

57. Summary: ID# 122-02, 45-year-old male, maximum Grade 3, first VGE at 25 minutes, first report at 84 minutes, study done on n = 11, crossover dependent sample statistical design.

Procedure 15

Narrative: At 84 minutes, subject reported a sharp pain in right elbow, like pain from the stick of a needle. Pain did not interfere with performance of formal exercise protocol. Did not report initial pain score on the 1–10 scale. Pain score was not reported at 120 minutes, but it was reported as 0 at 179 minutes. At 96 minutes, subject reported that right elbow was still a little painful, but not like it was at report from the row machine. No VGE detected from left arm or right arm, but Grade 2 VGE were detected after 25 minutes in the right and left leg. First VGE detected at 25 minutes, Grade 0 from left arm, Grade 2 from left leg, Grade 0 from right arm, and Grade 2 from right leg. Last VGE record at 169 minutes with Grade 0 from left arm, Grade 0 from left leg, Grade 0 from right arm, and Grade 0 from right leg. Grade increased to 3, mostly in right leg. Test was terminated earlier than planned at just less than 3 hours due to a Type II symptom in his chamber mate (121-01). There were no symptoms prior to descent; symptoms resolved at the test altitude of 4.3 psia. During debrief, pain in right elbow was described as having come on quickly, and as stabbing needles. Pain was continuous at lower levels but did not interfere with subject's ability to perform the exercises. Subject said pain in right shoulder was over the scapula area, and only lasted 10 minutes.

Diagnosis: Grade 2 Type I DCS
Treatment: One-hour GLO with follow-up consultation.

Bends 8a:(no prior treadmill exercise) DCS Assigned at JSC

58. Summary: ID# 146-02, 35-year-old male, maximum Grade 1, first VGE at 37 minutes, first report at 54 minutes a symptom he noticed at 42 minutes, study done on n = 40, crossover dependent sample statistical design.

Procedure 16

Narrative: At 54 minutes, subject reported pain in both right knee and left knee. Reported initial pain score of 6 on a 1–10 scale, but said right knee was more severe than left knee. During previous period at Doppler monitoring station, he said pain became more severe and standing did not help it. He first noticed symptoms in right knee at about 42 minutes; then about 3 minutes later, the left knee began to ache. Pain score increased to 8 at 60 minutes into test. Due to the intolerable nature and rapid onset of the knee pains, a decision was made to remove subject from the chamber. Initiated repressurization at 60 minutes. First VGE detected at 37 minutes, Grade 0 from left arm, Grade 0 from left leg, Grade 0 from right arm, and Grade 1 from right leg. Last VGE record at 37 minutes with Grade 0 from left arm, Grade 0 from left leg, Grade 0 from right arm, and Grade 1 from right leg. Symptoms in both knees improved during descent such that at 10.1 psia discomfort had decreased to a pain score of 3 while standing. Symptoms completely resolved during descent at 11.34 psia. During debrief, subject said right knee ache was first like a muscle "kink." He said that both knees and thigh (first time mentioned in notes) had fairly severe pain in the joint. This last statement is as clear as debrief notes allow.

Diagnosis: Grade 3 Type I DCS
Treatment: Two-hour GLO with follow-up consultation.

59. Summary: ID# 139-02, 23-year-old male, maximum Grade 0, first report at 80 minutes a symptom he noticed moments earlier, study done on n = 40, crossover dependent sample statistical design.

Procedure 16

Narrative: At 80 minutes, subject reported awareness in right ankle. Reported initial pain score of 2 on a 1–10 scale. Awareness did not interfere with exercise activities, and subject realized symptom moments earlier. Pain score remained constant at 2 at 120 minutes for right ankle. Subject also volunteered a pain score of 1 for a slight ache in middle of the back at 120 minutes. At 3rd-hour questioning, there was still a pain score 2 in right ankle. Last VGE record at 174 minutes with Grade 0 from left arm, Grade 0 from left leg, Grade 0 from right arm, and Grade 0 from right leg. No VGE were detected in this subject. Symptoms in right ankle resolved during descent at 8.8 psia.

Diagnosis: Grade 1 Type I DCS
Treatment: One-hour GLO with follow-up consultation.

60. Summary: ID# 147-01, 42-year-old male, maximum Grade 4, first VGE at 64 minutes, first report at 104 minutes, study done on n = 40, crossover dependent sample statistical design.

Procedure 16

Narrative: At 104 minutes, subject reported occasional pain in left knee. At 2nd-hour questioning, subject reported that left knee still hurt slightly, with steady pain. Reported pain score of 1 on a 1–10 scale. At 120 minutes, subject reported that left knee still hurt slightly; steady pain at patella. Pain does not interfere with movement. At 140 minutes, subject made his last report that left knee still hurt, and the test was terminated 3 minutes later since a second subject (149-01) had been removed earlier and was undergoing HBO treatment that could not be interrupted with a second case of DCS that might require HBO. First VGE detected at 64 minutes, Grade 2 from left arm, Grade 2 from left leg, Grade 0 from right arm, and Grade 3 from right leg. Last VGE record at 137 minutes with Grade 2 from left arm, Grade 4 from left leg, Grade 0 from right arm, and Grade 3 from right leg. Symptoms in left knee resolved during descent at 7.65 psia.

Diagnosis: Grade 2 Type I DCS
Treatment: One-hour GLO with follow-up consultation.

61. Summary: ID# 138-01, 44-year-old male, maximum Grade 4, first VGE at 29 minutes, first report at 60 minutes, study done on n = 40, crossover dependent sample statistical design.

Procedure 16

Narrative: At 60 minutes, subject reported awareness in right knee. Did not report initial pain score on the 1–10 scale. Initially reported at 45 minutes mild pain in left upper arm that extended along bicep during the Pull Station exercise. At 51 minutes, there was no arm pain while working at the Crank Station exercise. At the time of the report about the right knee, there was no further pain in left upper arm. At 83, 95, and 120 minutes there was no pain in right knee. First VGE detected at 29 minutes, Grade 0 from left arm, Grade 3 from left leg, Grade 0 from right arm, and Grade 2 from right leg. Last VGE record at 177 minutes with Grade 0 from left arm, Grade 4 from left leg, Grade 0 from right arm, and Grade 4 from right leg. Subject completed test and reported no symptoms at 180 minutes. There were no symptoms prior to descent; symptoms resolved at the test altitude of 6.5 psia. Pain reoccurred in right knee at a more severe level 15 hours after the test. He reported soreness in both knees.

Diagnosis: Grade 2 Type I DCS
Treatment: One-hour GLO and USN TT V HBO for reoccurrence of right knee symptom with symptom resolution. Follow-up consultation the next day.

62. Summary: ID# 133-02, 31-year-old female, maximum Grade 4, first VGE at 41 minutes, first report at 105 minutes, study done on n = 40, crossover dependent sample statistical design.

Procedure 16

Narrative: At 105 minutes, subject reported sharp intermittent pain in right leg, from knee to ankle. Reported initial pain score of 1 on a 1–10 scale on movement of right leg. There was no pain score report at 120 minutes, but subject reported stiffness in right knee. At about 124 minutes, subject reported pain in right leg; it was sharp and intermittent only on movement. At 143 minutes, subject reported that she could not straighten her right leg, and the pain score had increased to 3.5–4.0. After 158 minutes, she reported severe pain on movement of both the right knee and right ankle and lesser continuous pain at both sites. Test was terminated for subject at this time. First VGE detected at 41 minutes, Grade 0 from left arm, Grade 0 from left leg, Grade 0 from right arm, and Grade 3 from right leg. Last VGE record at 138 minutes with Grade 0 from left arm, Grade 4 from left leg, Grade 0 from right arm, and Grade 4 from right leg. Symptoms in right knee were gone by 10.1 psia, with right ankle pain gone near site pressure at about 13.7 psia. Posttest VGE monitoring 48 minutes after start of repressurization showed no VGE. Onset of fatigue reported 20 minutes after reaching site pressure, which subject attributed to a long day of exercise. Limb pain reoccurred after 2.5 hours on O_2.

Diagnosis: Grade 3 Type I DCS
Treatment: A 2.5-hour GLO and USN TT V HBO with symptom resolution. Follow-up consultation the next day.

63. Summary: ID# 127-01, 25-year-old male, maximum Grade 4, first VGE at 63 minutes, first report at 129 minutes, study done on n = 40, crossover dependent sample statistical design.

Procedure 16

Narrative: At 129 minutes, subject reported pain in right ankle. Reported initial pain score of 1 on a 1–10 scale. Pain was described as diffuse, and more in the right foot and towards the medial boarder. There was no tingling or numbness. The pain was on both sides of the right foot. At 145 minutes, symptom was reduced and described as a mild discomfort in right ankle. At 161 minutes, subject mentioned that pain around the right ankle was more noticeable at the Doppler station when his weight was off his feet, and was not present during other exercise activities. At 166 minutes, subject reported a new symptom of numbness under right knee, with discomfort still present on right ankle. At 175 minutes, a pain score of 8 was reported for top of right foot, with numbness still present under right knee, very slight and similar to the effects of Novocain (subject's words). The 3-hour test was terminated at this time. First VGE detected at 63 minutes, Grade 0 from left arm, Grade 2 from left leg, Grade 2 from right arm, and Grade 3 from right leg. Last VGE record at 156 minutes with Grade 2 from left arm, Grade 3 from left leg, Grade 3 from right arm, and Grade 4 from right leg. Symptoms from right ankle and right knee resolved during descent between 8.3 and 9.0 psia. Debrief comments were that discomfort in right ankle was like a lightly twisted ankle on both sides, with later pain on top of right foot described as if something heavy had stepped on top of foot. Subject said he changed the way he did the exercise activities to avoid involving right foot. Subject mentioned that right foot really bothered him toward the end of the test.

Diagnosis: Grade 3 Type I DCS
Treatment: One-hour GLO with follow-up consultation.

64. Summary: ID# 140-02, 24-year-old male, maximum Grade 4, first VGE at 40 minutes, first report at 60 minutes, study done on n = 40, crossover dependent sample statistical design.

Procedure 16

Narrative: At 60 minutes, subject reported aches in knuckles of right hand. Reported initial pain score of 1 on a 1–10 scale. At 72 minutes and 92 minutes, subject said that right hand did not hurt as much now. At 118 minutes, subject reported a pain score of 1 for right hip, a pain that was present for the last 4–5 minutes. Described as a slight but steady ache in the front part of the right hip. Right hand discomfort was almost gone at this time. Pain score at 120 minutes was still 1 in the hip. At 155 minutes, subject reported aches in right ankle and right knee, at same pain score as right hip, a value of 1. Just 2 minutes later, at 157 minutes, subject reported just the symptom in right hip; was not aware of any other symptoms. At 3rd-hour questioning, subject assigned a pain score of 1 to right hip and right ankle. First VGE detected at 40 minutes, Grade 0 from left arm, Grade 0 from left leg, Grade 1 from right arm, and Grade 0 from right leg. Last VGE record at 169 minutes with Grade 1 from left arm, Grade 2 from left leg, Grade 2 from right arm, and Grade 4 from right leg. Symptoms in right hip and right ankle resolved during descent at 7.65 psia.

Diagnosis: Grade 1 Type I DCS
Treatment: One-hour GLO with follow-up consultation.

Bends 8b (prior treadmill exercise): DCS Assigned at JSC

65. Summary: ID# 149-01, 40-year-old male, maximum Grade 4, first VGE at 45 minutes, first report at 108 minutes, study done on n = 41, crossover dependent sample statistical design.

Procedure 17

Narrative: At 108 minutes, subject reported irritation and itching on the chest. During 3rd VGE measurement period, at 45 minutes into exposure, Grade 3 VGE were detected when the left leg was flexed. Grade 4 VGE were detected from left leg and right leg at 77, 92, and 108 minutes. Bubble signals were more intense at 92 and 108 minutes and were assigned a Grade 4+. Last VGE record at 108 minutes with Grade 1 from left arm, Grade 4 from left leg, Grade 3 from right arm, and Grade 4 from right leg. Between 108 and 120 minutes, subject described irritation and itching on chest. There was blue and red marbling on the right side of chest. Skin mottling was diagnosed 120 minutes into the exposure. Subject was removed through a transfer airlock at 126 minutes. Rash and mottling reduced on descent, with mild redness at site pressure.

Diagnosis: Type II DCS (at this time, CM by itself was also classified as Type II DCS at JSC)
Treatment: One-hour GLO and USN TT V, and the mottling resolved before treatment ended. Follow-up consultation the next day.

A 40-year-old male, 80.9 kg, 174 cm, with 21% computed body fat and 26.7 BMI, participated in an altitude exposure at JSC. Subject had no previous altitude exposure as a research subject. Subject ascended to 6.5 psia for a 3 hour exposure while breathing 100% O_2 through a mask. Prior to the ascent, there was a brief ear and sinus check

done by depressurizing the chamber atmosphere to the equivalent of 6,000 feet altitude in about 1 minutes (5,000 feet/minute). Subject breathed air during this check, which took approximately 5 minutes for all subjects to be evaluated, primarily during the repressurization back to site pressure. The medical technician exited the chamber and an ascent on air to 10 psia at 6,500 feet/minute was begun 6 minutes from the start of the initial ascent. About 2 minutes later subject donned the O_2 mask at 10 psia and the chamber continued the ascent to 6.5 psia at 6,500 feet/ minutes. The ascent time to 6.5 psia was 12 minutes with subject breathing 100% O_2 for 10 minutes. Exercise stressed the upper body since 4 minutes were spent flexing the wrist, elbow, and shoulder joints while rhythmically rotating the wheel of a bicycle ergometer against a set resistance from a standing position, 4 minutes torquing fixed bolts with either the left or right hand from a standing position, and 4 minutes of rhythmically pulling against a set resistance from a seated position. The details of these exercises are available. Finally, there was a 4 minutes period of rest and a 4 minutes period of bubble monitoring with subject asked to flex each limb in turn while in a supine position. Subject ambulated to the three exercise stations within the chamber. During the third VGE measurement period, at 45 minutes into the exposure, Grade III VGE were detected when the left leg was flexed. Grade IV VGE were detected from the left and right legs at 77, 92, and 108 minutes. The bubble signals were more intense during the 92 and 108 minutes times and were assigned a Grade IV+. Between 108 and 120 minutes subject described irritation and itching on the chest. There was blue and red marbling on the right side of the chest. Skin mottling was diagnosed 120 minutes into the exposure. Subject was removed through a transfer airlock at 126 minutes. Rash and mottling reduced on descent, with mild redness at site pressure. Subject was treated on a USN TT V, and the mottling resolved before the treatment ended.

66. Summary: ID# 157-01, 28-year-old female, maximum Grade 0, first report at 120 minutes a symptom she noticed at about 117 minutes, study done on n = 41, crossover dependent sample statistical design.

Procedure 17

Narrative: At 120 minutes, during 2nd-hour questioning, subject reported dull ache in right wrist that had started about 3 minutes earlier. Reported initial pain score of 3 on a 1–10 scale that was only present while exercising. No VGE were detected at this time. Pain score decreased to 1 at 138 and 180 minutes. At 138 minutes, the dull ache was still present but reduced to pain score of 1. By end of the 3-hour test, the same dull ache in right wrist was just a little worse during the exercise. Last VGE record at 174 minutes with Grade 0 from left arm, Grade 0 from left leg, Grade 0 from right arm, and Grade 0 from right leg. No VGE were detected during the test. Mentioned she was hot, the chamber air conditioning was off. Said she was fatigued from the exercise profile. Symptoms in right wrist resolved during descent at 7.34 psia.

Diagnosis: Grade 1 Type I DCS
Treatment: Two-hour GLO with follow-up consultation.

67. Summary: ID# 158-01, 26-year-old male, maximum Grade 4, first VGE at 56 minutes, first report at 111 minutes a symptom he noticed minutes earlier, study done on n = 41, crossover dependent sample statistical design.

Procedure 17

Narrative: At 111 minutes, subject reported that left ankle hurt. Reported initial pain score of 1 on a 1–10 scale. Discomfort was noticed at the Doppler station, and decreased on walking. Subject reported a dull ache in left shoulder and a cramp in left side during deep inspiration from between 90 to 100 minutes into the test. All of these symptoms were attributed to the exercise

devices, and improved during the evolution of the left ankle symptom. Pain score for the left ankle increased to 2 at 123 minutes, and was most noticeable at the Doppler station. Pain score reported to decrease to 1 by 138 minutes. Subject reported a slight pain in the left ankle at 152 minutes on a pain score of 1–2, and a very slight awareness or dull pain just below the patella on right side of left knee at less than a 1 on pain score. At 180 minutes, during final interview about symptoms, subject reported the same slight pain in left ankle during flexion of joint, but didn't notice symptom while walking. First VGE detected at 56 minutes, Grade 0 from left arm, Grade 2 from left leg, Grade 0 from right arm, and Grade 0 from right leg. Last VGE record at 168 minutes with Grade 0 from left arm, Grade 4 from left leg, Grade 0 from right arm, and Grade 0 from right leg. Symptoms in left ankle and left knee resolved during descent at 10.1 psia.

Diagnosis: Grade 1 Type I DCS
Treatment: Two-hour GLO with follow-up consultation.

68. Summary: ID# 164-01, 27-year-old male, maximum Grade 4, first VGE at 44 minutes, first report at 79 minutes, study done on n = 41, crossover dependent sample statistical design.

Procedure 17

Narrative: At 79 minutes, subject reported a mild transient dull ache in left knee. Reported initial pain score of 2 on a 1–10 scale. Pain score remained constant at 2 at 112 minutes, and then decreased to 1 at 146 minutes. At 3rd-hour questioning, subject mentioned that the left knee hurt during movement at the Doppler station; about a 2 on the pain score. Also detected mild pain in left ankle, at a pain score of 1. First VGE detected at 44 minutes, Grade 0 from left arm, Grade 4 from left leg, no measurement from the right arm, and Grade 0 from right leg. Last VGE record at 178 minutes with Grade 0 from left arm, Grade 3 from left leg, Grade 0 from right arm, and Grade 0 from right leg. Symptoms in left knee and left ankle resolved during descent at 8.1 psia.

Diagnosis: Grade 1 Type I DCS
Treatment: Two-hour GLO with follow-up consultation.

69. Summary: ID# 140-01, 24-year-old male, maximum Grade 4, first VGE at 20 minutes, first report at 97 minutes, study done on n = 41, crossover dependent sample statistical design.

Procedure 17

Narrative: At 97 minutes. subject reported mild or slight pain in right thumb. Reported initial pain score of 1–2 on a 1–10 scale. At 2nd-hour questioning, subject reported no change in right thumb symptom. At 163 minutes, subject reported slight pain in right knee, on a pain score of 1–2. Pain was located beneath patella, with no change in symptom on flexion or extension of right leg. At 170 minutes, subject reported no pain in right thumb, no change in right knee. At 3rd-hour questioning, subject reported pain in right knee had almost gone. First VGE detected at 20 minutes, Grade 0 from left arm, Grade 0 from left leg, Grade 1 from right arm, and Grade 1 from right leg. Last VGE record at 168 minutes with Grade 0 from left arm, Grade 4 from left leg,

Grade 0 from right arm, and Grade 4 from right leg. Symptoms in right knee resolved during descent at 7.65 psia.

Diagnosis: Grade 1 Type I DCS
Treatment: One-hour GLO with follow-up consultation.

70. Summary: ID# 139-01, 23-year-old male, maximum Grade 4, first VGE at 42 minutes, first report at 60 minutes, study done on n = 41, crossover dependent sample statistical design.

Procedure 17

Narrative: At 60 minutes, subject reported discomfort in outer fingers of left hand. Did not report initial pain score on a 1–10 scale. There was no numbness, or change in sensorium. At 86 minutes, subject reported no change in discomfort of left hand. Mentioned that he became cold during ascent, but the sensation left. As it left, the first VGE began to appear and with them the discomfort in left hand began. Grade 2 VGE detected from left arm at 42 minutes, then Grade 4 at 64 minutes. No other VGE were detected in left leg, right leg, or right arm. At 98 minutes, pain diminished and there was no further numbness or change in sensorial. Last Grade 4 VGE were recorded at 84 minutes, with lesser grades detected for the duration of the test. Last VGE record at 172 minutes with Grade 1 from left arm, Grade 0 from left leg, Grade 0 from right arm, and Grade 0 from right leg. At 126 minutes, there was no pain, but still an awareness. At 138 minutes, there was no residual pain, the left hand did not hurt, but awareness was present. At 146 minutes, there was still some awareness in left hand. He still had some pain in left hand prior to descent. On descent, all symptoms in left hand cleared at 7.43 psia.

Diagnosis: Grade 1 Type I DCS
Treatment: One-hour GLO with follow-up consultation.

71. Summary: ID# 137-02, 24-year-old male, maximum Grade 4, first VGE at 59 minutes, first report at 120 minutes a symptom he noticed at about 105 to 110 minutes, study done on n = 41, crossover dependent sample statistical design.

Procedure 17

Narrative: At 120 minutes, during 2nd-hour questioning, subject reported slight pain in left knee. Reported initial pain score of 1 on a 1–10 scale, but only during extension of the left leg. Subject relayed that pain had started about 10–15 minutes earlier. Pain score remained constant at 1 at 120 and 128 minutes. At 140 minutes, subject reported a reduction in symptom in the left knee to a 0 on the 1–10 pain score. At 3rd-hour questioning, he reported no symptoms from left knee. First VGE detected at 59 minutes, Grade 0 from left arm, Grade 4 from left leg, Grade 0 from right arm, and Grade 2 from right leg. Last VGE record at 168 minutes with Grade 0 from left arm, Grade 4 from left leg, Grade 0 from right arm, and Grade 0 from right leg. Logbook did not document whether or not subject reported if there was a change in left knee symptoms during descent. But during posttest debriefing, he mentioned that pain had disappeared on return to site

pressure. He also volunteered that he experienced an extremely mild pain in his teeth, but no other details were available.

Diagnosis: Grade 2 Type I DCS
Treatment: One-hour GLO with follow-up consultation.

72. Summary: ID# 136-01, 26-year-old female, maximum Grade 4, first VGE at 37 minutes, first report at 60 minutes a symptom she noticed at 40 minutes, study done on n = 41, crossover dependent sample statistical design.

Procedure 17

Narrative: At 60 minutes, during 1st-hour questioning, subject reported mild discomfort in right elbow. Reported initial pain score of 3–4 on a 1–10 scale. Subject volunteered that discomfort was present for about 20 minutes. At 87 minutes, subject reported that pain in right elbow was less than previously reported, and still a little stiff. At 120 minutes, she reported slight uncomfortable pressure in left knee. She said knee pain was detected about 16 minutes earlier. Also, pain in the right elbow was gone. At 141 minutes, left knee pain score increased to 4–5. A new right knee pain also appeared and was given a pain score of 2. She mentioned that it would be "difficult to bend knee if had to." A decision was made to terminate test for this subject, and at 146 minutes subject was returning to site pressure via the transfer lock. First VGE detected at 37 minutes, Grade 2 from left arm, Grade 2 from left leg, Grade 2 from right arm, and Grade 4 from right leg. Last VGE record at 132 minutes with Grade 0 from left arm, Grade 4 from left leg, Grade 0 from right arm, and Grade 4 from right leg. Subject reported symptoms in both knees had cleared by 10.5 psia. During debrief, subject described elbow pain as sharp, like a sprain. Knee symptoms were described as a deeper and more throbbing pain. Pain reoccurred after 18 hours. It is not clear from the logbook it reoccurring pain was in one or both knees.

Diagnosis: Grade 3 Type I DCS
Treatment: One-hour GLO and TT VI HBO with symptom resolution. Follow-up consultation the next day.

73. Summary: ID# 133-01, 31-year-old female, maximum Grade 4, first VGE at 25 minutes, first report at 137 minutes a symptom she noticed moments earlier, study done on n = 41, cross-over dependent sample statistical design.

Procedure 17

Narrative: At 137 minutes, subject reported a sharp pain in right knee while bending right leg at the Doppler station. Reported initial pain score of 3–4 on a 1–10 scale. At 157 minutes, subject reported right knee was more tense when extending the leg. Symptom was scored as a 6 on pain score. Since extension of the leg was impaired, a decision was made to terminate the test. Initiated repressurization at 166 minutes. First VGE detected at 25 minutes, Grade 0 from left arm, Grade 0 from left leg, Grade 0 from right arm, and Grade 2 from right leg. Last VGE record at 156 minutes with Grade 0 from left arm, Grade 2 from left leg, Grade 0 from right arm, and

Grade 4 from right leg. By 166 minutes during repressurization, pain in the right knee was still present at 7.9 psia. All right knee symptoms resolved during descent at 9.0 psia.

Diagnosis: Grade 3 Type I DCS
Treatment: Two-hour GLO with follow-up consultation.

74. Summary: ID# 31-06, 39-year-old male, maximum Grade 4, first VGE at 76 minutes, first report at 144 minutes a symptom he noticed moments earlier, study done on n = 41, crossover dependent sample statistical design.

Procedure 17

Narrative: At 144 minutes, subject reported mild pain in right ankle and right knee, just below joint in the right knee. Reported initial pain score of 1–2 on a 1–10 scale. Pain was noticed during right leg motion at the Doppler station and was described as intermittent, not interfering with assigned exercises. Pain score remained at same low level of 1 at 180 minutes in the right knee. There was no further pain in the right ankle at the time of repressurization. First VGE detected at 76 minutes, Grade 0 from left arm, Grade 0 from left leg, Grade 0 from right arm, and Grade 1 from right leg. Last VGE record at 175 minutes with Grade 0 from left arm, Grade 1 from left leg, Grade 0 from right arm, and Grade 4 from right leg. Symptoms in right knee lessened during descent at 7.2 psia, and there was only a slight awareness at 9.7 psia. No symptoms were present at site pressure.

Diagnosis: Grade 1 Type I DCS
Treatment: One-hour GLO with follow-up consultation.

Bends 9a (ambulatory control): DCS Assigned at JSC

75. Summary: ID# 172-01, 33-year-old female, maximum Grade 4, first VGE at 173 minutes, first report at 179 minutes, study done on n = 24, crossover dependent sample statistical design.

Procedure 18

Narrative: At 179 minutes, during 3rd-hour questioning, subject reported pain in left leg and left thigh, but no pain in left knee. Reported initial pain score of 5 on a 1–10 scale. Pain was described as not radiating. Pain score decreased to 4 at 190 minutes, and the test was over so descent began. First and last VGE detected at 173 minutes, Grade 0 from left arm, Grade 3 from left leg, Grade 0 from right arm, and Grade 4 from right leg. Symptom pain score intensity in left leg decreased to 1 at 10.1 psia; there were no symptoms in left leg at 12.2 psia, nor any residual symptoms at site pressure. VGE still detected after test at site pressure. VGE at 219 minutes was Grade 0 from left arm, Grade 1 from left leg, Grade 0 from right arm, and Grade 2 from right leg. During debrief, done with subject breathing 100% O_2, symptoms were described as pain in left leg in the thigh and calf area, not radiating, not related to the knee joint, nor did it interfere with the exercise activity. Since the test was over and descent started approximately 12 minutes after the first report, it was not possible to follow the evolution of symptoms.

Diagnosis: Grade 2 Type I DCS
Treatment: Two-hour GLO, medical observation for 12 hours with follow-up consultation.

Bends 9b (adynamic): DCS Assigned at JSC

76. Summary: ID# 130-03, 28-year-old male, maximum Grade 3, first VGE at 52 minutes, first report after test, during the later part of the 3-hour altitude exposure, study done on n = 23, crossover dependent sample statistical design.

Procedure 19

Narrative: Subject did not report symptoms during test. During debrief, he mentioned mild pain in left knee during later part of altitude exposure. Pain resolved during return to site pressure. A review of his Questionnaire on Post-Exposure Symptoms also uncovered a comment that left hip joint also experienced pain along with left knee. He wrote that he experienced a cold sweat from 10.1 psia on down to site pressure. He also experienced slight fatigue and weakness in the legs and lower back after standing up. Recall that this subject had been bed rested for the about 4 days, which included the time at 6.5 psia. First VGE detected at 52 minutes, Grade 1 from left arm, Grade 3 from left leg, Grade 1 from right arm, and Grade 0 from right leg. Last VGE record at 181 minutes with Grade 0 from left arm, Grade 1 from left leg, Grade 1 from right arm, and Grade 2 from right leg. Subject did not report if there was a change in symptoms during descent.

Diagnosis: Grade 1 Type I DCS
Treatment: One-hour GLO with follow-up consultation.

77. Summary: ID# 184-01, 52-year-old male, maximum Grade (see explanation below), first VGE at (see explanation below), first report at 113 minutes, study done on n = 23, crossover dependent sample statistical design.

Procedure 19

Narrative: At 113 minutes, subject reported itching and burning across the chest and axilla. Reported initial pain score of 2 on a 1–10 scale. Pain score was not reported at 136, 148, or 180 minutes into the test. Last VGE record at 179 minutes with Grade 0 from left arm, Grade 0 from left leg, Grade 0 from right arm, and Grade 0 from right leg. The MO suspected contact dermatitis. At 2nd-hour questioning, subject reported no problems other than the mild skin irritation. At 136 minutes, the DT reported an increased size of redness on the abdomen. Subject no longer reported itching, but reported that areas felt hot. All agreed to monitor subject closely, but to continue the test. At 148 minutes, the DT reported that the sizes of the patches had increased on the abdomen, with whitening of certain areas. No bubbles were detected from a precordial position using a 2-mHz Doppler probe; and since symptoms were limited to slight burning, the decision was made to finish the test. Best diagnosis at the time was contact dermatitis. At 3rd- (and last) hour questioning, subject reported that skin irritation around stomach was no worse than earlier. Subject did not report if there was a change in skin symptoms during descent. At site pressure, 189 minutes from start of exercise at 6.5 psia, the DT reported that there was no change in the

skin colors. Subject was allowed to remove his O_2 mask. Subject had minimal mottling on the return to site pressure. He also experienced postural hypotension and dizziness on standing, which persisted after he left the chamber area.

Diagnosis: Type II DCS (at this time, CM by itself was also classified as Type II DCS at JSC)
Treatment: USN TT V about 4.5 hours after return to site pressure, at which time a rash was still evident. Treatment lasted 90 minutes, with no extensions since dizziness was judged to have diminished. Subject was held for observation through the night. At 21:00, the rash was still evident. At 06:30 the following day, the rash was reported as almost cleared on the lower abdomen, and greatly diminished in the left axilla. Postural hypotension confounds a proper characterization of DCS since prolonged bed rest was part of the study design. Subject displayed a Doppler blood flow signal during the test that differed from that normally encountered in hypobaric/hyperbaric decompressions. Normally, the presence of individual gas bubbles can be heard in the flow signal; but here, individual bubble signals were absent. Instead, when limb movement maneuvers occurred, the intensity of flow sound increased. Our opinion is that this is indicative of an increased number of scattering sites; the absence of individual, audible bubbles would indicate that these were microbubbles. Subject did have a PFO, with positive indication at rest.

A 52-year-old male, 80.6 kg, 179 cm, with 21% computed body fat and 25 BMI, participated in an altitude exposure at JSC. Subject had no previous altitude exposure as a research subject. Subject ascended to 6.5 psia for a 3 hour exposure while breathing 100% O_2 through a mask. Prior to the ascent, there was a brief ear and sinus check done by depressurizing the chamber atmosphere to the equivalent of 6,000 feet altitude in about 1 minutes (5,000 feet/minutes). The ascent time to 6.5 psia was 12 minutes with subject breathing 100% O_2 for 10 minutes. Subject was under strict bed rest conditions for three days prior to the ascent to simulate adaptation to microgravity. Subject stayed in a supine position during the altitude exposure. Exercise stressed the upper body, since 4 minutes were spent flexing the wrist, elbow, and shoulder joints while rhythmically rotating the wheel of an arm ergometer against a set resistance from a supine, 4 minutes torquing fixed bolts with either the left or right hand from a supine position, and 4 minutes of rhythmically pulling against a set resistance from a supine position. The details of these exercises are available. Finally, there was a 4 minutes period of rest and a 4 minutes period of bubble monitoring with subject asked to flex each limb in turn while in a supine position. Subject reported itching and burning across the chest (2 out of 10 from a pain scale) and axilla at 113 minutes into the exposure. The MO suspected contact dermatitis. At the seconds hour questioning period subject reported no problems other than the mild skin irritation. At 136 minutes the DT reported an increased size of the redness on the abdomen. Subject no longer reported itching, but reported that the areas felt hot. All agreed to monitor subject closely, but to continue the test. At 148 minutes the DT reported that the sizes of the patches had increased on the abdomen, with whitening of certain areas. No bubbles were detected from a precordial position using a 2 mHz Doppler probe, and since the symptoms were limited to slight burning the decision was made to finish the test. However, subject displayed a Doppler blood flow signal during the test that was different from that normally encountered in hypo- or hyperbaric decompressions. Normally, the presence of individual gas bubbles can be heard in the flow signal, but in this case, individual bubble signals were absent. Instead, when the limb movement maneuvers occurred, the intensity of the flow sound increased. Our opinion is that this is indicative of an increased number of scattering sites; the absence of individual, audible bubbles would indicate that these were microbubbles. The best diagnosis at the time was still contact dermatitis. At the third (and last) hour questioning period subject reported that the skin irritation around the stomach was no worse than earlier. At site pressure, 189 minutes from start of exercise at 6.5 psia, the DT reported that there was no change in the skin colors. Subject was allowed to remove his O_2 mask. A series of photographs were taken of the torso following the return to site pressure (exact time is unavailable). The posttest comments in the logbook stated that subject had minimal mottling on the return to site pressure. Subject also experienced postural hypotension and dizziness on standing, and it persisted after he left the chamber area. A decision was made to treat subject on a USN TT V about 4.5 hour after the return to site pressure, at which time a rash was still evident. The treatment lasted 90 minutes, with no extensions since the dizziness was judged to have diminished. Subject was held for observation through the night. At 9:00 p.m. the rash was still evident. At 6:30 a.m. the following day, the rash was reported as almost cleared on

the lower abdomen, and greatly diminished in the left axilla. The postural hypotension confounds a proper characterization of DCS since prolonged bed rest was part of the study design.

Bends 9c (ambulatory control): DCS Assigned at JSC

78. Summary: ID# 202-01, 40-year-old female, maximum Grade 4, first VGE at 38 minutes, first report at 114 minutes a symptom she noticed at about 94 minutes, study done on n = 11, crossover dependent sample statistical design.

Procedure 20

Narrative: At 114 minutes, subject reported persistent pain in left knee. Reported initial pain score of 3 on a 1–10 scale. Symptom had appeared about 20 minutes earlier and was now feeling better and never interfered with exercise activities. Pain score remained constant at 3 at 180 minutes, but became worse while standing. At 140 minutes, subject reported that pain in the left knee felt better while standing (2–3 score), and assigned it a score of 3 while sitting, but still not interfering with exercise activities. At 152 minutes, subject reported pain in left knee was much reduced; a score of 1 or lower. During the 3rd-hour questioning, subject reported a pain score 1 for left knee, and a new pain or sensation at pain score 1 in left ankle. First VGE detected at 38 minutes, Grade 2 from left arm, Grade 4 from left leg, Grade 2 from right arm, and Grade 4 from right leg. Last VGE record at 174 minutes with Grade 3 from left arm, Grade 4 from left leg, Grade 3 from right arm, and Grade 3 from right leg. Symptoms resolved during descent in left knee at 5.0 psia and in left ankle at 5.8 psia.

Diagnosis: Grade 2 Type I DCS
Treatment: One-hour GLO with follow-up consultation.

79. Summary: ID# 204-01, 36-year-old male, maximum Grade 4, first VGE at 47 minutes, first report at 82 minutes a symptom he noticed at 80 minutes, study done on n = 11, crossover dependent sample statistical design.

Procedure 20

Narrative: At 82 minutes, subject reported pain in right ankle. Reported initial pain score of 1 on a 1–10 scale. He reported that pain started 2 minutes earlier, and was more noticeable during movement of ankle at the VGE monitoring station. At 87 minutes, subject reported pain in right ankle was gone. At 157 minutes, subject reported pain in right knee had started about 2 minutes earlier, but was not interfering with the exercise activities. Pain was constant, on a score of 2–3. No symptoms from right ankle. Pain score was constant at 2–3 just prior to descent at 180 minutes. First VGE detected at 47 minutes, Grade 0 from left arm, Grade 3 from left leg, Grade 3 from right arm, and Grade 4 from right leg. Last VGE record at 173 minutes with Grade 3 from left arm, Grade 3 from left leg, Grade 3 from right arm, and Grade 3 from right leg. Symptoms resolved in right knee during descent at 8.6 psia.

Diagnosis: Grade 2 Type I DCS
Treatment: Two-hour GLO with follow-up consultation.

80. Summary: ID# 207-01, 31-year-old male, maximum Grade 4, first VGE at 62 minutes, first report at 165 minutes, study done on n = 11, crossover dependent sample statistical design.

Procedure 20

Narrative: At 165 minutes, subject reported minor pain in left knee. Did not provide initial pain score on a 1–10 scale. Pain was continuous, but did not interfere with exercise activities. First VGE detected at 62 minutes, Grade 1 from left arm, Grade 4 from left leg, Grade 1 from right arm, and Grade 4 from right leg. Last VGE record at 166 minutes with Grade 3 from left arm, Grade 4 from left leg, Grade 3 from right arm, and Grade 3 from right leg. Symptoms in left knee resolved during descent at 10.2 psia. During debrief, subject mentioned that he had a transient symptom in right knee that he did not report during the test.

Diagnosis: Grade 1 Type I DCS
Treatment: One-hour GLO with follow-up consultation.

Bends 10: DCS Assigned at JSC

81. Summary: ID# 192-01, 31-year-old male, maximum Grade 4, first VGE at 20 minutes, first report at 158 minutes a symptom he noticed moments earlier, study done on n = 19, independent sample statistical design.

Procedure 21

Narrative: At 158 minutes, subject reported mild joint awareness in left elbow. Reported initial pain score of 1 on a 1–10 scale. He noticed pain during the previous Doppler monitoring period. At 178 minutes, there was no pain. Bubbles first detected Grade 1 from right leg at 20 minutes, which increased in grade and stayed at Grade 3 during the last monitoring periods. At the same time, left arm, right arm, and left leg contributed Grade 1 and 2 from about 55 minutes for the duration of the test. First VGE detected at 20 minutes, Grade 0 from left arm, Grade 0 from left leg, Grade 0 from right arm, and Grade 1 from right leg. Last VGE record at 165 minutes with Grade 2 from left arm, Grade 1 from left leg, Grade 2 from right arm, and Grade 3 from right leg. There were no symptoms prior to descent; symptoms resolved at the test altitude of 10.1 psia.

Diagnosis: Grade 1 Type I DCS
Treatment: One-hour GLO with follow-up consultation.

Bends 11: DCS Assigned at JSC

82. Summary: ID# 215-01, 25-year-old male, maximum Grade 3, first VGE at 96 minutes, first report at 145 minutes a symptom he noticed at 144 minutes, study done on n = 28, independent sample statistical design.

Procedure 22

Narrative: At 145 minutes, subject reported mild pain under the patella and to the left of right knee. Reported initial pain score of 1 on a 1–10 scale. He noticed symptom 1 minute earlier. First VGE detected at 96 minutes, Grade 2 from left arm, Grade 2 from left leg, Grade 2 from right arm, and Grade 3 from right leg. Last VGE record at 133 minutes with Grade 2 from left arm, Grade 2 from left leg, Grade 2 from right arm, and Grade 3 from right leg. After 96 minutes, subject had Grade 3 VGE from right leg and Grades 1 and 2 assigned to the other 3 limbs. At the time of symptom report at 145 minutes, VGE grade was still 3 from right leg. Subject suggested, and the MO concurred, that he should stand and flex right leg to further evaluate this mild pain. Subject reported that mild pain had now abated and was not present once he returned to his seat. By this time, subject had been seated for 335 minutes. Decision was made by MO to abort the test. Entire test was terminated at 148 minutes into the 240 minutes test. There were no symptoms prior to descent; symptoms resolved at the test altitude of 4.3 psia.

Diagnosis: Grade 1 Type I DCS
Treatment: Two-hour GLO with follow-up consultation.

83. Summary: ID# 228-01, 40-year-old female, maximum Grade 4, first VGE at 101 minutes, first report at 153 minutes, study done on n = 28, independent sample statistical design.

Procedure 22

Narrative: At 153 minutes, subject reported dull pain under and inside right patella. Pain did not increase on extension of right leg. At 101 minutes into test, Grade 2 VGE detected from left leg. First VGE detected at 101 minutes, Grade 0 from left arm, Grade 0 from left leg, Grade 0 from right arm, and Grade 0 from right leg. Last VGE record at 153 minutes with Grade 1 from left arm, Grade 3 from left leg, Grade 1 from right arm, and Grade 4 from right leg. At 117 minutes, VGE were Grade 2 from left leg and Grade 3 from right leg. At 137 minutes, VGE were Grade 4 from left leg and Grade 4+ from right leg. Entire test was terminated at approximately 160 minutes into the 240-minute test. Pain in right knee resolved during descent at 6.75 psia. Grade 3 VGE detected from right leg at 175 minutes while at site pressure, and Grade 0 from all limbs by 194 minutes.

Diagnosis: Grade 1 Type I DCS
Treatment: Two-hour GLO with follow-up consultation.

84. Summary: ID# 234-01, 31-year-old female, maximum Grade 4, first VGE at 32 minutes, first report at 48 minutes, study done on n = 28, independent sample statistical design.

Procedure 22. Same as Procedure 22 except one subject had a problem with ear block that effectively added another 10 minutes to the 3-hour PB.

Narrative: At 48 minutes, subject reported a dull ache in right wrist that was noticeable without exercise. At 54 minutes, subject said it felt better after MO questioning, and MO continued test with instructions for subject to keep the MO informed of any changes in right wrist. At 32 minutes, Grade 2 VGE were detected from left leg and right leg and Grade 4 from right arm. At 51 minutes, Grade 3 VGE from left arm and right leg, with Grade 4 from left leg and right arm. At 68 minutes, all limbs showed Grade 4 VGE. Last VGE record at 68 minutes with Grade 4 from left arm, Grade 4 from left leg, Grade 4 from right arm, and Grade 4 from right leg. At 1st-hour questioning, subject said there was still discomfort in right wrist without activity, and it did not feel worse with exercise. She said this discomfort was not felt during the pre-test exercise practice in the Environmental Lab. At 72 minutes, during Doppler monitoring, subject reported pain in left wrist. It was same pain as in right wrist. The entire test was terminated at 76 minutes into the 240-minute test. Pain in right wrist resolved during descent at 4.56 psia and from left wrist at 4.99 psia.

Diagnosis: Grade 1 Type I DCS
Treatment: Two-hour GLO with follow-up consultation.

Phase I PRP: DCS Assigned at Duke

85. Summary: ID# D980113C, 23-year-old female, maximum Grade 3, first VGE at 75 minutes, first report at 76 minutes, study done on n = 47, independent sample statistical design.

Procedure 23

Narrative: At 76 minutes, subject reported soreness in right ankle, which progressed over ensuing 10 minutes to a constant deep ache. At 86 minutes, she reported pain score of 3 on a 1–10 scale. She had no other problems, but could be observed to favor her right leg during the Pull Station exercises. At 94 minutes, she reported a persistent "weird aching feeling" in left ankle, joined by new complaint of pain in bottom of left foot, all on a 3 pain score. Preparations were made for subject lockout. Lockout preparations took about 15 minutes (about 110 minutes elapsed time from start of test), by which time subject noted onset of right knee pain. During move to chamber lock, subject experienced a bout of lightheadedness, probably orthostatic. First VGE detected at 75 minutes, Grade 0 from right arm, Grade 0 from left arm, Grade 0 from left leg, and Grade 0 from right leg. Last VGE record at 104 minutes with Grade 0 from right arm, Grade 2 from left arm, Grade 2 from left leg, and Grade 3 from right leg. All symptoms in both ankles and right knee resolved on descent.

Diagnosis: Type I DCS
Treatment: Prophylactic USN Table V was given. Follow-up consultation the next day.

86. Summary: ID# D980120B, 46-year-old male, maximum Grade 4, first VGE at 16 minutes, first report at 113 minutes, study done on n = 47, independent sample statistical design.

Procedure 23

Narrative: At 113 minutes, subject reported pain or ache in left knee that differed from any he had before in his left knee. Reported initial pain score of 2 on a 1–10 scale. By 181 minutes, the pain was gone and the exposure had finished uneventfully. First VGE detected at 16 minutes, Grade 2 from right arm, Grade 2 from left arm, Grade 3 from left leg, and Grade 2 from right leg. VGE detected at time of the left knee report at 113 minutes was Grade 2 from right arm, Grade 1 from left arm, Grade 4 from left leg, and Grade 2 from right leg. The last complete VGE record at 197 minutes with Grade 2 from right arm, Grade 3 from left arm, Grade 4 from left leg, and Grade 2 from right leg. Four days later, subject reported numbness in left foot at base of toes, which resolved spontaneously within a few hours. Seven days postflight the numbness in left foot at base of toes returned. No objective abnormality was found on examination, but tissues deep to the skin at the base of toes on left foot felt numb. Hyperbaric treatment was initiated.

Diagnosis: Type I DCS
Treatment: USN TT VI with full resolution of symptoms in last O_2 period. Consulting MO "finds it difficult to believe these purely subjective features are due to the same (left knee) disorder, with onset 4 days after the trial. However, I cannot otherwise account for his complaint." Follow-up consultation the next day.

87. Summary: ID# D980203B, 22-year-old female, maximum Grade 1, first VGE at 74 minutes, first report at 111 minutes, study done on n = 47, independent sample statistical design.

Procedure 23

Narrative: At 111 minutes, subject reported twitching on lateral surface of left calf. Pinprick sensation was evaluated during this time with no difference of sensation reported over involved area. First VGE detected at 74 minutes, Grade 0 from right arm, Grade 0 from left arm, Grade 1 from left leg, and Grade 0 from right leg. Last VGE record at 242 minutes with Grade 0 from right arm, Grade 0 from left arm, Grade 0 from left leg, and Grade 0 from right leg. Symptom resolved by 180 minutes. There were no symptoms prior to descent; symptoms resolved at the test altitude of 4.3 psia. With return to surface, subject had no symptoms at rest; but upon rising from semi-supine position, she noticed a very mild discomfort in lateral, distal aspect of her right thigh, which she reported was apparent only while walking when right foot struck the floor. Subject was in mid-menstrual cycle and reported taking Loestrin. At 505 minutes, subject returned to FGHL after having reported being awakened from a nap by pain in right wrist at 21:30. On interview at 23:20, she noted that in addition to right wrist pain, she had also experienced transient numbness of the ends of fingers on right hand, which had resolved. Also noted that right hand felt colder than left hand, a sensation that persisted into the interview. Original discomfort in right thigh was unchanged. Hyperbaric treatment was initiated.

Diagnosis: Type I DCS
Treatment: USN TT VI and both wrist and residual leg pain completely resolved within about 5 minutes of reaching depth. Compression was extremely slow (approximately 12 minutes) due to problems equalizing ears. Follow-up consultation the next day.

88. Summary: ID# D980210A, 21-year-old female, maximum Grade 0, first report at 164 minutes, study done on n = 47, independent sample statistical design.

Procedure 23

Narrative: At 164 minutes, subject reported a headache and feeling hot during exposure. Reported initial pain score of 2 on a 1–10 scale. No VGE were detected in this subject. Last VGE record at 228 minutes with Grade 0 from right arm, Grade 0 from left arm, Grade 0 from left leg, and Grade 0 from right leg. Subject completed exposure. At 1,649 minutes from start of altitude exposure (17:00 the day after the exposure), subject called FGHL (2/11/98) with complaint of intermittent pain in right elbow and right wrist throughout the day. Noted that on awakening in the morning (day immediately following the EVA day), she had some tingling in her right wrist and forearm, which quickly resolved. She remained unaware of any significant wrist or elbow pain until later in the day when, with the performance of manual tasks, she noted stiffness in both her right wrist and elbow that was worst immediately following use of her hands and improved with rest. Subject was symptom free and without complaint at 17:00, the time of the 2/11/98 call. Subject elected to wait until following morning to report to FGHL, when she was otherwise already scheduled to participate in another research study. On 2/12/98, subject reported to FGHL in morning. On physical examination, subject was found to be entirely within normal limits, specifically normal neurological to light touch, pinprick, normal reflexes and normal strength. However, subject complained of mild intermittent discomfort in right wrist and right elbow. She added that she would occasionally experience light twinges of tingling in her right hand, that her right hand did not feel normal (although no sensory deficit), and that she generally did not feel normal. Hyperbaric treatment was initiated.

Diagnosis: Type I DCS
Treatment: USN TT VI and on arrival at 60 fsw [feet seawater] while breathing 100% O_2 subject reported full relief of joint pain, but still-persistent abnormal feeling in right hand. Follow-up consultation the next day.

89. Summary: ID# D980303B, 27-year-old female, maximum Grade 3, first VGE at 60 minutes, first report at 134 minutes, study done on n = 47, independent sample statistical design.

Procedure 23

Narrative: At 134 minutes, subject reported onset of pain in dorsum of left wrist. Reported initial pain score of 3 on a 1–10 scale. Pain worsened to a level 4 with distraction force (pulling) and improved to a level 2 with compressive force on wrist. Pain score improved spontaneously to 2.5 after about 30 minutes of continued activity, but never completely resolved. Pain improved by 163 minutes but never completely resolved. Evaluation by inside tender demonstrated no

abnormal pinprick sensation, and no visible cutaneous changes were evident. Subject was otherwise symptom-free. Persistence of symptoms in left wrist motivated a decision to remove subject from the chamber at 211 minutes. First VGE detected at 60 minutes, Grade 1 from right arm, Grade 1 from left arm, Grade 2 from left leg, and Grade 2 from right leg. Last VGE record at 204 minutes with Grade 0 from right arm, Grade 0 from left arm, Grade 0 from left leg, and Grade 0 from right leg. During descent at 10.11 psia, subject reported distal migration of pain to dorsum of left hand, still at a 2.5 pain score. At 12.69 psia, subject reported tingling in 4^{th} and 5^{th} digits of left hand. During evaluation at site pressure while subject on 100% O_2, subject reported additional onset of left thumb pain, but improved digit tingling and resolution of left wrist and hand pain. Hyperbaric treatment initiated.

Diagnosis: Type I DCS
Treatment: Posttest O_2 until USN TT VI started. All remaining symptoms resolved. Subject returned for reevaluation 8-hour post USN TT VI reporting residual tenderness along ulnar aspect of left forearm, wrist, and 5th digit. On examination, tenderness was found to worsen with palpation and resisted motion at the wrist. Otherwise subject without complaint of recurrent neurological symptoms in fingers, hand, or wrist. New complaints consistent with mild tendonitis from EVA exercises. Subject instructed to begin course of nonsteroidal anti-inflammatory medication for treatment. On follow-up 5 days later (3/9/98), mild residual tendonitis persisted but was improving. Subject, having returned to normal activity without residual deficit, reported being pleased with treatment course and recovery.

Phase I PRP: DCS Assigned at Hermann

90. Summary: ID# H980219A, 45-year-old male, maximum Grade 4, first VGE at 108 minutes, first report at 110 minutes, study done on n = 47, independent sample statistical design.

Procedure 23

Narrative: At 110 minutes, subject reported pain on left side of left knee. Reported initial pain score of 3 on a 1–10 scale, and pain was constant. Maximum VGE grades were 1 from right arm, 1 from left arm, 4 from left leg, and 3 from right leg. First VGE detected at 108 minutes, Grade 1 from right arm, Grade 1 from left arm, Grade 4 from left leg, and Grade 3 from right leg. Last VGE record at 228 minutes with Grade 0 from right arm, Grade 0 from left arm, Grade 2 from left leg, and Grade 3 from right leg. Pain report at 119 minutes into test was constant and mild at 2 or 3 on 10-point scale. Subject reported that pain felt like it was in the joint and it did not interfere with performance. Pain also continued at rest. At 128 minutes, pain was constant at a level of 2. At 196 minutes, subject described pain as awareness during the exercise, and a 0.5 on pain score in left knee. Subject remained at 4.3 psia for the duration of the 4-hour test. Some time during the descent to site pressure, awareness in left knee was completely gone.

Diagnosis: Type I DCS. MO diagnosed DCS at 119 minutes, but for unknown reasons allowed the test to continue to the end.
Treatment: One-hour GLO with follow-up consultation.

91. Summary: ID# H980226A, 28-year-old male, maximum Grade 3, first VGE at 76 minutes, first report at 144 minutes a symptom he noticed moments earlier, study done on n = 47, independent sample statistical design.

Procedure 23

Narrative: At 144 minutes, subject reported pain on lateral-left ankle and under the patella of left knee. Reported initial pain score of 1 on a 1–10 scale. Pain was intermittent at the beginning but within 1 or 2 minutes became constant. Pain in left knee was described as intermittent at first and then became more constant under the patella. Pain seemed to have started shortly after the extension of left leg upon Doppler monitoring. First VGE detected at 76 minutes, Grade 0 from right arm, Grade 0 from left arm, Grade 3 from left leg, and Grade 2 from right leg. Last VGE record at 144 minutes with Grade 2 from right arm, Grade 2 from left arm, Grade 3 from left leg, and Grade 3 from right leg. Subject was locked out. Symptoms in left knee and left ankle cleared at 7.2 psi.

Diagnosis: Type I DCS
Treatment: One-hour GLO with follow-up consultation.

92. Summary: ID# H980310A, 26-year-old male, maximum Grade 3, first VGE at 76 minutes, first report at 76 minutes, study done on n = 47, independent sample statistical design.

Procedure 23

Narrative: At 76 minutes, subject reported continuous pain on external side of left ankle. Reported initial pain score of 3 on a 1–10 scale. Subject had Grade 3 VGE from left leg at this time. First VGE detected at 77 minutes, Grade 0 from right arm, Grade 0 from left arm, Grade 1 from left leg, and Grade 2 from right leg. Last VGE record at 92 minutes with Grade 1 from right arm, Grade 1 from left arm, Grade 3 from left leg, and Grade 3 from right leg. Subject wanted to continue exercises and, at 92 minutes, reported pain in right ankle. Subject was locked out. All symptoms in both ankles cleared at 5.2 psi.

Diagnosis: Type I DCS. MO diagnosed DCS in left ankle after 76 minutes but subject wanted to continue test. The MO ended test after the second report of pain in right ankle at 92 minutes.
Treatment: One-hour GLO with follow-up consultation.

93. Summary: ID# H980324B, 29-year-old female, maximum Grade 3, first VGE at 76 minutes, first report at 76 minutes, study done on n = 47, independent sample statistical design.

Procedure 23

Narrative: At 76 minutes, subject reported a feeling of tingling (like an itch) on both lower extremities. Subject had Grade 2 VGE from left leg at this time. First VGE detected at 77 minutes, Grade 0 from right arm, Grade 0 from left arm, Grade 2 from left leg, and Grade 0 from right leg. Last VGE record at 160 minutes with Grade 1 from right arm, Grade 3 from left arm,

Grade 3 from left leg, and Grade 3 from right leg. Subject wanted to continue the test and, at 108 minutes, subject also reported tingling in left arm as well as original sensation in lower extremities. At 128 minutes, subject had Grade 3 VGE from left leg and the tingling sensation on both legs and left arm was becoming more intense. Sensation had expanded to both thighs. At 144 minutes, sensation became more intense on outer thigh. At 160 minutes, subject had Grade 3 VGE in both legs and said that tingling had expanded to the lower back area and the hips. Subject was locked out at 160 minutes, and all tingling symptoms resolved at 8.0 psi with some residual awareness on left thigh. During the MO interview after the test, subject reported that she had left knee and hip pain on a pain score of 3–4. At the end of postflight PB, subject was symptom free and was discharged by the on-call MO. NOTE: The 10-minute PB exercise was too hard for subject to keep up with her legs. Resistance was decreased from the prescribed 133 to 83 for 4 minutes then back to 133. Target heart rate peaked at 189.

Diagnosis: Type I DCS
Treatment: One-hour GLO with follow-up consultation.

Phase III PRP: DCS Assigned at Duke

94. Summary: ID# D980630B, 29-year-old female, maximum Grade 0, first report at 52 minutes, study done on n = 10, independent sample statistical design.

Procedure 25

Narrative: At 52 minutes, subject reported a headache on right anterior side of skull. Reported initial pain score of 1 on a 1–10 scale. Reported bilateral sinus pain at 67 minutes. At 101 minutes, subject reported right shoulder ache while exercising. At 142 minutes, right shoulder pain was reported to have increased with a pain score of 1 assigned to it, and was present during exercise and rest. At 137 minutes, subject reported headache was at a pain score of 1.5 severity, and her eyes were dry. At 192 minutes, right shoulder pain had increased to a pain score of 2 and had become constant to persist throughout exercise and rest. Subject had no VGE. Last VGE record at 203 minutes with Grade 0 from right arm, Grade 0 from left arm, Grade 0 from left leg, and Grade 0 from right leg. Subject was locked out at 207 minutes with complete relief of shoulder symptoms. Subject experienced difficulty clearing her ears and sustained bilateral ear barotraumas. NOTE: Subject had a history of shoulder dislocation (side not specified) in childhood. Sacroiliac pain treated by chiropractor within 12 months preceding altitude test.

Diagnosis: Type I DCS. Ear examination revealed moderately injected tympanic membranes with some hemorrhaging.
Treatment: Two-hour GLO with follow-up consultation.

95. Summary: ID# D980714C, 42-year-old male, maximum Grade 4, first VGE at 105 minutes, first report at 143 minutes, study done on n = 10, independent sample statistical design.

Procedure 25

Narrative: At 143 minutes, subject reported itching on arms and legs (right side from an earlier e-mail). At 149 minutes, subject reported a "numb" feeling from heal to toe of right foot. At 169 minutes, subject reported being "numb all over". Shortly after this report, subject reported right knee pain. First VGE detected at 105 minutes, Grade 0 from right arm, Grade 0 from left arm, Grade 1 from left leg, and Grade 0 from right leg. Last VGE record at 156 minutes with Grade 0 from right arm, Grade 1 from left arm, Grade 4 from left leg, and Grade 4 from right leg. Subject was returned to site pressure at this time, but symptoms persisted at site pressure.

Diagnosis: Type II DCS
Treatment: Multiple hyperbaric treatments. Initial intermittent symptoms of right arm and right leg numbness progressed to include right-sided sensorimotor changes, right knee pain, unsteady gait, visual scotomata, disorientation, and confusion. These symptoms responded to a full USN TT VI, but recurred after surfacing. A second recompression treatment was performed, on a TT VI with Catalina Extensions (more 100% O_2 than a standard TT VI). Following this, patient was admitted to hospital. His condition markedly improved, with minimal neurological findings remaining. Brain MRI [magnetic resonance imaging] was normal. Bubble contrast echocardiogram showed PFO at rest. Follow-up hyperbaric treatments were administered during next 2 days, and follow-up neurological examinations were normal.

MO Consult Note, Time of Consult: 15:20 July 14, 1998
Reason for Consult: Decompression Illness resulting from NASA Study.

HISTORY OF PRESENT ILLNESS: The patient is a 42 year old white Caucasian male who was participating in a physiology experiment today in the Duke Hyperbaric Chamber on 14 July 1998. His first symptom was itching on the arms and legs that began 143 minutes (clock time 15:12) after arrival at 30,000 feet (4.3 psia). Prior to ascent he had breathed 100% O_2 for 2 hour and continued breathing 100% O_2 while at altitude. At altitude, the patient did intermittent mild arm and leg exercise according to the experimental protocol. 6 minutes after the onset of itching he noted a "numb" feeling from heel to toe. Over the course of the next 10 minutes the symptoms did not progress and became intermittent for a time. It was decided to observe closely but continue the protocol so long as symptoms continued to resolve. At this point the diagnosis of altitude DCS had not been made since transient sensory changes in extremities on this protocol are not uncommon. Approximately 26 minutes after the first symptom onset he reported being "numb all over." He said it came as a "flash" but did not persist. Shortly after that, right knee pain also developed. At this point (30 minutes after the initial itching) the diagnosis and DCS was made and preparations to return the patient to 1 ATA were begun immediately. As preparations were underway the leg numbness returned and he noted spots and lines in front of his eyes. Twelve minutes later he was at 1 ATA. Upon entering the transfer chamber for return to 1 ATA, he noted he was unsteady and actually fell down at one point. Upon reaching 1 ATA the patient was taken to the physiology laboratory where he was seated. The patient appeared dazed and did not respond to verbal queries as if he couldn't hear. But after finally getting his attention, it was determined that his hearing was normal and that he was oriented to person, place, and time.

PHYSICAL EXAMINATION: The patient appeared mildly confused and displayed a very flat affect but answered all questions correctly during examination. His speech seemed slow and deliberate. He was oriented to person, place, and time. Strength and cranial nerves were normal. There was decreased sensation to pinprick in the right arm compared to the left. He complained his right arm and leg felt numb. Finger-to-nose was slow and deliberate without past pointing. His normal Rhomberg showed significant unsteadiness. He could not perform tandem gait and his sharpened Rhomberg was less than 2 seconds. He was administered the same neurobehavioral cognitive exam that we used for evaluating CO patients and this was within normal limits. Proprioception was tested by moving the great toe up and down. He was consistently correct on the left but occasionally incorrect on the right. He was at 1 ATA approximately 50 minutes from the time he exited the altitude chamber until the time he was recompressed and during that time he said that he felt "less out of it" and was feeling a little better. During his time at 1 ATA while being examined he breathed air.

IMPRESSION: Decompression sickness due to altitude exposure.

DISPOSITION: Compressed to 60 feet, execute USN TT VI.

TREATMENT PROGRESS: Treatment Table VI was started at 16:47 on 15 July 1998, 50 minutes after leaving the altitude chamber. After the 1st O_2 period at 60 feet, there were no changes in his gait or his Rhomberg. The patient now noted some scintillating scotoma in both eyes. After the 2nd O_2 breathing period at 60 feet, the patient noted that the right leg numbness was markedly decreased and his arm felt almost normal. His tandem gait had improved. After three O_2 breathing periods at 60 feet and following the 30-minutes ascent to 30 feet, his tandem gait became completely normal and he was able to walk the length of the chamber heel to toe with his eyes closed. A sharpened Rhomberg was greater than 15 seconds. His speech and affect were normal as determined by the inside chamber tender. At this point complete resolution of symptoms had occurred. The patient surfaced from the TT VI at approximately 21:34. Immediately upon exiting the chamber, the patient was noted to be speaking and walking normally and went off to the bathroom to urinate and change clothes. During my interview 10 minutes after surfacing, the patient again appeared dazed. He did not respond to all the questions appropriately and he kept saying that he had "lost his bearings". He said that his right arm and leg began to go numb about 10 minutes just before arriving at the surface during the final ascent from 30 feet. On physical examination his affect was flat and his speech is somewhat deliberate. He always paused before answering a question, but eventually got the right answer. The right arm is slightly weaker than left in flexors and extensors. Pinprick on the right arm and leg was decreased compared to the left. Pinprick on both sides of the abdomen and thorax was normal. He was unable to do a tandem gait or a sharpened Rhomberg and kept falling to the right. His finger-to-nose was very slow and deliberate but there was no past pointing. Approximately 40 minutes after surfacing, he felt faint and began to collapse to the floor but was caught before he did so and immediately taken into the chamber and put in one of the treatment chairs. In the chamber the examination continued as preparations for recompression were begun. No nystagmus was noted but he did complain of feeling nauseated and eventually vomited his stomach contents that consisted mainly of pizza that he had eaten during the first treatment. The patient then became totally unresponsive to verbal commands for a few seconds but did not lose consciousness. He did respond to a loud voice but did not respond meaningfully to commands. He was not oriented at this time. Forty-5 minutes after surfacing from the first treatment, he was recompressed to 60 feet and began 100% O_2 breathing periods. After arrival at 60 feet the patient was still dazed and was not responding meaningfully to the tenders questions. The inside chamber tender would put his hands on parts of the patient's body and ask him to identify them, but the patient was unable to do so. He had a completely flat affect and responded only slowly and deliberate to commands. An IV of D5W was started and run at approximately one liter. Additional hyperbaric treatments, a test for PFO, and a complete neurological work-up followed. Was found to have a resting PFO.

Phase IV PRP: DCS Assigned at Hermann

96. Summary: ID# H990511A, 29-year-old male, maximum Grade 0, first report at 92 minutes, study done on n = 57, independent sample statistical design.

Procedure 26

Narrative: At 92 minutes, subject reported mild pain just below right knee. Reported initial pain score of 1–2 on a 1–10 scale. Subject also described a prickly hot and cold sensation on skin on top of right foot first and then on top of left foot. Subject was asked to move around and remove his shoes. This was felt to be due to postural effects and not related to DCS. Subject had no VGE. Last VGE record at 84 minutes with Grade 0 from right arm, Grade 0 from left arm, Grade 0 from left leg, and Grade 0 from right leg. Subject was locked out. Symptom in right knee resolved during descent to site pressure.

Diagnosis: Type I DCS
Treatment: Two-hour GLO with follow-up consultation.

97. Summary: ID# H990527B, 24-year-old male, maximum Grade 3, first VGE at 64 minutes, first report at 84 minutes, study done on n = 57, independent sample statistical design.

Procedure 26

Narrative: At 84 minutes, subject reported only a mild aching pain on left knee. Some time later, subject reported a sharp, constant pain on left knee under patella. Reported pain score of 7 on a 1–10 scale. Subject selected United States Air Force (USAF) Grade 2 pain as appropriate descriptive index. Subject said that pain started about 10 minutes earlier as a sensation of awareness. First VGE detected at 64 minutes, Grade 0 from right arm, Grade 0 from left arm, Grade 3 from left leg, and Grade 0 from right leg. Last VGE record at 80 minutes with Grade 0 from right arm, Grade 0 from left arm, Grade 3 from left leg, and Grade 0 from right leg. Subject was locked out. Symptoms in the left knee resolved during descent at 7.3 psia with no residual pain at site pressure.

Diagnosis: Type I DCS
Treatment: Two-hour GLO with follow-up consultation.

98. Summary: ID# H990610A, 25-year-old male, maximum Grade 2, first VGE at 45 minutes, first report at 45 minutes, study done on n = 57, independent sample statistical design.

Procedure 26

Narrative: At 45 minutes, subject reported mild aching of right knee. Reported initial pain score of 2 on a 1–10 scale and then 3–4 a short time later. Subject first complained of hot spots at 12 minutes into the 4.3-psia exposure. VGE detected at 45 minutes, Grade 0 from right arm, Grade 0 from left arm, Grade 0 from left leg, and Grade 2 from right leg. Last VGE record was also at 45 minutes with Grade 0 from right arm, Grade 0 from left arm, Grade 0 from left leg, and Grade 2 from right leg. Decision was made to remove subject from test. Subject was locked out approximately 50 minutes into test. Symptoms in right knee resolved during descent at 12.7 psia with no residual pain at site pressure.

Diagnosis: Type I DCS
Treatment: Two-hour GLO with follow-up consultation.

99. Summary: ID# H990615B, 28-year-old male, maximum Grade 3, first VGE at 169 minutes, first report at 183 minutes, study done on n = 57, independent sample statistical design.

Procedure 26

Narrative: At 183 minutes, subject reported mild intermittent aching in left knee. Pain was intermittent but could be noticed when leg was extended. Reported initial pain score of 3 on a 1–

10 scale. Subject was asked to reposition himself to determine whether the sensation was due to positional/postural causes. Pain disappeared with repositioning, but then returned when left leg was stretched out. First VGE detected at 169 minutes, Grade 0 from right arm, Grade 0 from left arm, Grade 3 from left leg, and Grade 0 from right leg. Last VGE record at 247 minutes with Grade 0 from right arm, Grade 0 from left arm, Grade 3 from left leg, and Grade 0 from right leg. Decision was made to remove subject from test, but the scheduled end of test had arrived so no lockout was required. Symptoms in left knee resolved during descent with no residual pain at site pressure.

Diagnosis: No DCS. Diagnosis was epicondylitis (tennis elbow) due to repeated arm and handwork the previous day.
Treatment: Two-hour GLO. Phoned next day with report of tenderness in left elbow. Given a USN TT V treatment, with no relief. Was given anti-inflammatory medication. Follow-up consultation the next day.

Phase IV PRP: DCS Assigned at DCIEM

100. Summary: ID# C990311B, 28-year-old male, maximum Grade 3, first VGE at 31 minutes, first report at 31 minutes, study done on n = 57, independent sample statistical design.

Procedure 26

Narrative: At 31 minutes, subject reported discomfort in left knee aggravated by exercise. First VGE detected at 31 minutes, Grade 0 from right arm, Grade 0 from left arm, Grade 3 from left leg, and Grade 0 from right leg. Last VGE record was also at 31 minutes with Grade 0 from right arm, Grade 0 from left arm, Grade 3 from left leg, and Grade 0 from right leg. Subject was locked out at 48 minutes. Symptoms in left knee cleared at 10.92 psia.

Diagnosis: Type I DCS
Treatment: Two-hour GLO with follow-up consultation.

101. Summary: ID# C990315D, 45-year-old male, maximum Grade 4, first VGE at 40 minutes, first report at 56 minutes, study done on n = 57, independent sample statistical design.

Procedure 26

Narrative: At 56 minutes, subject reported discomfort in left knee, fading in and out. Reported initial pain score of 2 on a 1–10 scale. At 68 minutes, the report was still intermittent level 2 pain score in left knee. At 72 minutes, subject reported a slight improvement, and it was decided to remove subject from test. First VGE detected at 40 minutes, Grade 0 from right arm, Grade 0 from left arm, Grade 0 from left leg, and Grade 3 from right leg. Last VGE record at 56 minutes with Grade 0 from right arm, Grade 1 from left arm, Grade 4 from left leg, and Grade 1 from right leg. Subject was locked out at 74 minutes. Symptoms in left knee cleared shortly after start of descent.

Diagnosis: Type I DCS
Treatment: Two-hour GLO with follow-up consultation.

102. Summary: ID# C990317D, 41-year-old male, maximum Grade 4, first VGE at 93 minutes, first report at 118 minutes, study done on n = 57, independent sample statistical design.

Procedure 26

Narrative: At 118 minutes, subject reported a sore left leg. At 121 minutes, reported steady discomfort. At this time, subject reported initial pain score of 2–3 on a 1–10 scale. At 124 minutes, reported left knee pain was 4–5 on the pain score. First VGE detected at 93 minutes, Grade 0 from right arm, Grade 0 from left arm, Grade 3 from left leg, and Grade 0 from right leg. Last VGE record at 109 minutes with Grade 0 from right arm, Grade 2 from left arm, Grade 4 from left leg, and Grade 2 from right leg. Subject was locked out at 129 minutes. Symptoms in left knee cleared at 9.35 psia.

Diagnosis: Type I DCS
Treatment: Two-hour GLO with follow-up consultation.

103. Summary: ID# C990324C, 35-year-old male, maximum Grade 4, first VGE at 40 minutes, first report at 92 minutes, study done on n = 57, independent sample statistical design.

Procedure 26

Narrative: At 92 minutes, subject reported awareness in right ankle and right knee. At 108 minutes, he reported constant awareness in right ankle and right knee, not a pain. At 116 minutes, he reported increased awareness in right knee at a 1–2 pain score on a 10-point pain scale with right ankle awareness less noticeable. First VGE detected at 40 minutes, Grade 0 from right arm, Grade 0 from left arm, Grade 0 from left leg, and Grade 2 from right leg. Last VGE record at 108 minutes with Grade 2 from right arm, Grade 3 from left arm, Grade 3 from left leg, and Grade 4 from right leg. Subject was locked out at 116 minutes. Symptoms were mostly gone at 6.75 psia with significant ear clearing problems below 7.34 psia. Subject had no symptoms in right ankle or right knee at 9.35 psia.

Diagnosis: Type I DCS
Treatment: Two-hour GLO with follow-up consultation.

Selected Narratives where DCS was not Diagnosed

Bends 1c: Narratives but no DCS Assigned at JSC

1. Summary: ID# 16-01, 21-year-old male, maximum Grade 1, first VGE at 26 minutes, first report after the end of the test during debrief, estimated at 120 minutes into the test, study done on n = 11, independent sample statistical design.

Procedure 3

Narrative: During debrief, subject mentioned that he felt some transient pain in middle of left foot, and tightening in left knee similar to what he experiences when running. He recalled that this appeared at the beginning of the second hour at 4.3 psia. Did not report initial pain score on the 1–10 scale. First VGE detected at 26 minutes, Grade 0 from left arm, Grade 1 from left leg, Grade 0 from right arm, and Grade 0 from right leg. Last VGE record at 169 minutes with Grade 0 from left arm, Grade 0 from left leg, Grade 0 from right arm, and Grade 0 from right leg. Subject did not report if there was a change in any symptoms during descent. During debrief, subject described symptoms he had during the test to the PI. Since symptoms in the left foot and left knee were still present at site pressure, a hyperbaric treatment was given. Symptoms did not respond to hyperbaric treatment.

Diagnosis: No DCS
Treatment: HBO provided to evaluate symptoms still present in left foot and left knee, but treatment table was not noted in the logbook. Treatment did not resolve the symptoms, so these were attributed to the exercise protocol used during the test. Follow-up consultation the next day.

Bends 2a: Narratives but no DCS Assigned at JSC

2. Summary: ID# 29-02, 43-year-old male, maximum Grade 0, first report at 72 minutes, study done on n = 23, independent sample statistical design.

Procedure 5

Narrative: At 72 minutes, during 1st-hour questioning, subject reported a little pain in left wrist that lasted about 30 seconds. Did not report initial pain score on the 1–10 scale. Subject had no VGE during the test. Last VGE record at 236 minutes with Grade 0 from left arm, Grade 0 from left leg, Grade 0 from right arm, and Grade 0 from right leg. It was out of normal protocol not to have a period of questioning for 2nd-, 3rd-, or 4th-hour questioning of this subject during test. Also During the test, 2 other chamber mates (37-02 and 21-02) were reporting symptoms that disrupted the normal flow of the experiment. There were no symptoms prior to descent; symptoms resolved at the test altitude of 4.3 psia. During debrief, subject described momentary symptom in left wrist as a pain or strain, which occurred during the ergometer cranking. It felt like a muscle strain, and did not occur for the duration of the test.

Diagnosis: No DCS
Treatment: None, just self-monitoring most likely with follow-up consultation.

Bends 3a: Narratives but no DCS Assigned at JSC

3. Summary: ID# 48-02, 36-year-old male, maximum Grade 0, first report at 342 minutes a symptom he noticed at about 322 minutes, study done on n = 28, independent sample statistical design.

Procedure 7

Narrative: At 342 minutes, subject reported intermittent pain under right shoulder. Did not report initial pain score on the 1–10 scale. He mentioned that symptom was first noticed about 20 minutes earlier (322 minutes). At 6th-hour questioning, he reported that for last 2 or 3 minutes the pain had become continuous and moved toward center of back. He had no VGE during the test. Last VGE record at 349 minutes with Grade 0 from left arm, Grade 0 from left leg, Grade 0 from right arm, and Grade 0 from right leg. Symptoms in back "pretty much gone" at 7.3 psia. During debrief at site pressure subject rated the intensity of pain in back a 1–2 pain score. It was questionable if symptoms in back cleared in a dramatic fashion, similar to what the PI had previously experienced.

Diagnosis: None, Grade 1 Type I DCS was initially diagnosed; but after re-review 1 week later, the PI classified this as exercise-induced symptoms since a history of these symptoms was documented in records of the pre-test exercise training and the indefinite verification of symptoms during recompression to site pressure.
Treatment: None, medical observation most likely for 12 hours with follow-up consultation.

Bends 3b: Narratives but no DCS Assigned at JSC

4. Summary: ID# 10-05, 45-year-old male, maximum Grade 2, first VGE at 161 minutes, first report at 180 minutes, study done on n = 35, independent sample statistical design.

Procedure 8

Narrative: At 180 minutes, during 3rd-hour questioning, subject reported constant discomfort in right shoulder. Reported initial pain score of 1–2 on a 1–10 scale. At the 4th-hour questioning, he said symptoms were the same, still a 1–2 pain score. First VGE detected at 161 minutes, Grade 0 from left arm, Grade 0 from left leg, Grade 2 from right arm, and Grade 0 from right leg. Next VGE monitoring was at 197 minutes, Grade 1 from left arm, Grade 2 from left leg, Grade 2 from right arm, and Grade 0 from right leg. Last VGE record at 360 minutes with Grade 0 from left arm, Grade 0 from left leg, Grade 0 from right arm, and Grade 0 from right leg. At 5th-hour questioning, he said discomfort was in right shoulder joint and muscle, on a 1–2 pain score, and was similar to how his shoulder felt after an injury he had about 1 year earlier. At 6th-hour questioning, subject reported symptoms in right shoulder were still on a 1–2 pain score. Symptoms in

right shoulder did not resolve during repressurization to site pressure. During debrief, subject mentioned he had constant discomfort from third hour on in right shoulder and right elbow. It still felt the same, on a 1–2 pain score. He was asked to crank the hand ergometer at 10.2 psia, the storage pressure prior to a second test the next day, and reported the same muscle soreness that he had previously reported.

Diagnosis: No DCS
Treatment: None, just self-monitoring most likely with follow-up consultation.

Bends 3d: Narratives but no DCS Assigned at JSC

5. Summary: ID# 43-05, 25-year-old male, maximum Grade 3, first VGE at 130 minutes, first report at 179 minutes, study done on n = 12, independent sample statistical design.

Procedure 10

Narrative: Subject had reported symptoms at first hour in left shoulder the day before while at 4.3 psia. The PI was not convinced these were symptoms of DCS. Subject was clear to perform second test. At 3rd-hour questioning, subject reported slight discomfort in left shoulder. Reported initial pain score of 2–3 on a 1–10 scale. Awareness radiated from left shoulder to left elbow; subject had awareness while was lying down. At 4th-hour questioning, subject reported less pain in left shoulder compared to the previous report, with a pain score of 1. At 293 minutes, subject reported pressure on chest, a small pain in chest when he inhaled. Did not feel any symptoms when lying down, but felt symptom when he took a deep breath. At 5th-hour questioning, subject reported no symptoms from left shoulder. Pain in chest was at a pain score of 6 at its worst, but there was no coughing or need to cough. At 323 minutes, subject was asked about chest symptoms, and said no pain had reoccurred. At 6th-hour questioning, subject reported no symptoms in left shoulder. Symptoms in chest were just present for 5 minutes. First VGE detected at 130 minutes, Grade 0 from left arm, Grade 1 from left leg, Grade 0 from right arm, and Grade 0 from right leg. Last VGE record at 356 minutes with Grade 0 from left arm, Grade 0 from left leg, Grade 0 from right arm, and Grade 0 from right leg. There were no symptoms prior to descent; symptoms resolved at the test altitude of 4.3 psia. During debrief at site pressure, subject mentioned that pain in left shoulder was worse today, and more constant, than he had experienced the day before on his first exposure to 4.3 psia. Chest pain was not diagnosed by the MO as chokes during the test.

Diagnosis: No DCS
Treatment: None, just self-monitoring most likely with follow-up consultation.

Bends 5a: Narratives but no DCS Assigned at JSC

6. Summary: ID# 94-01, 24-year-old female, maximum Grade 0, first report at 73 minutes, study done on n = 38, independent sample statistical design.

Procedure 12

Narrative: At 73 minutes, subject reported problem in right patella. Did not report initial pain score on the 1–10 scale. At 84 minutes, reported discomfort in right wrist. At 93 minutes, subject reported that problem in right knee was worse, and he felt it when at the Doppler station but not at the exercise stations. At 110 minutes, subject reported discomfort in right wrist was present throughout previous exercise. At 2nd-hour questioning, a constant dull ache present at all times in the right wrist, but feeling in the right knee was only present at the Doppler monitoring station. At 3rd-hour questioning, subject reported symptom in right wrist had not bothered her over the last hour, and that she felt the right knee symptom when she bent down. At 4th- and 5th-hour questioning, subject reported being just fine, with no symptoms in right knee or right wrist. No VGE were detected during test. Last VGE record at 324 minutes with Grade 0 from left arm, Grade 0 from left leg, Grade 0 from right arm, and Grade 0 from right leg. There were no symptoms prior to descent; symptoms resolved at the test altitude of 4.3 psia. During debrief, subject mentioned she still felt something in right knee while squatting down, and recalled that she might have hurt right knee earlier in the week while playing with her children.

Diagnosis: No DCS
Treatment: None, just self-monitoring most likely with follow-up consultation.

Bends 7 (high exercise): Narratives but no DCS Assigned at JSC

7. Summary: ID# 116-01, 33-year-old male, maximum Grade 4, first VGE at 0 minutes, did not report a symptom until after the test during debriefing period, study done on n = 11, cross-over dependent sample statistical design.

Procedure 14

Narrative: At about 30 minutes after the test, subject mentioned during the formal debriefing that he had "something" once during the test but it was exactly what he feels in some cramped positions, so he did not report anything. First VGE detected at 0 minutes, Grade 0 from left arm, Grade 0 from left leg, Grade 3 from right arm, and Grade 0 from right leg. It is very unusual to detect VGE early in the exposure, and even more unusual to detect VGE exclusively from the upper body. There was a rapid onset of VGE, with Grade 4 from the left and right legs at 96 minutes into the test. Last VGE record at 189 minutes with Grade 0 from left arm, Grade 3 from left leg, Grade 3 from right arm, and Grade 4 from right leg. Subject did not report if there was a change in symptoms during descent.

Diagnosis: No DCS
Treatment: One-hour GLO with follow-up consultation.

Bends 7 (low exercise): Narratives but no DCS Assigned at JSC

8. Summary: ID# 123-02, 28-year-old male, maximum Grade 4, first VGE at 76 minutes, first report at 120 minutes, study done on n = 11, crossover dependent sample statistical design.

Procedure 15

Narrative: At 120 minutes, during 2nd-hour questioning, subject reported tingling on skin of face, shoulders, and wrists. He also mentioned being intermittently warm. Did not report initial pain score on the 1–10 scale. First VGE detected at 76 minutes, Grade 0 from left arm, Grade 1 from left leg, Grade 0 from right arm, and Grade 1 from right leg. Last VGE record at 185 minutes with Grade 0 from left arm, Grade 3 from left leg, Grade 0 from right arm, and Grade 2 from right leg. At 3rd-hour questioning, subject said all skin sensations had disappeared about 30 minutes earlier. There were no symptoms prior to descent; symptoms resolved at the test altitude of 6.5 psia. Debrief notes indicate there was no rash on inspection of skin, and that symptoms could have been due to sweating early in the test.

Diagnosis: No DCS
Treatment: One-hour GLO with follow-up consultation .

Bends 8a (no prior treadmill exercise): Narratives but no DCS Assigned at JSC

9. Summary: ID# 122-03, 48-year-old male, maximum Grade 4, first VGE at 24 minutes, first report at 120 minutes, study done on n = 40, crossover dependent sample statistical design.

Procedure 16

Narrative: At 120 minutes, during 2nd-hour questioning, subject reported a warm head and forearm muscle stiffness during the Pull Station exercises. Did not provide initial pain score on a 1–10 scale. Subject and DT had reported being warm about 20 minutes into the test. At 150 minutes, subject reported that stiffness in forearms was about the same, and that they felt a little sore. At 160 minute,s subject reported a sinus headache localized to the ethmoid sinus. Headache was gradual in its onset, and subject felt it was related to O_2 flow in the mask. At 174 minutes, sinuses still hurt, mostly around the eyes. No visual disturbances mentioned. First VGE detected at 24 minutes, Grade 2 from left arm, Grade 3 from left leg, Grade 0 from right arm, and Grade 0 from right leg. Last VGE record at 168 minutes with Grade 2 from left arm, Grade 4 from left leg, Grade 2 from right arm, and Grade 4 from right leg. During repressurization, subject reported that his sinuses hurt more than at 6.5 psia. Chamber descent was stopped at 2,000 feet returned to 3,000 feet, and a sinus spray was administered to help open the sinuses. During debrief, subject was asked to pull on the Pull Station ergometer; he noted that his forearms still hurt a little, but not as much as at altitude. It is noted in the logbook that the Pull Station ergometer resistance was higher than the training ergometer in the Environmental Physiology Laboratory. Sinusitis improved.

Diagnosis: No DCS
Treatment: One-hour GLO with follow-up consultation.

Bends 8b (prior treadmill exercise): Narratives but no DCS Assigned at JSC

10. Summary: ID# 51-12, 32-year-old male, maximum Grade 1, first VGE at 175 minutes, first report at 60 minutes, study done on n = 41, crossover dependent sample statistical design.

Procedure 17

Narrative: At 60 minutes, during 1st-hour questioning, subject reported slight pain in right elbow. Reported initial pain score of 1 on a 1–10 scale. Pain was described as steady, and did not change with exercise. Subject mentioned that he had not experienced this sensation during ground training of the exercise activities. First VGE detected at 175 minutes, Grade 0 from left arm, Grade 1 from left leg, Grade 0 from right arm, and Grade 0 from right leg. Last VGE record was also at 175 minutes with Grade 0 from left arm, Grade 1 from left leg, Grade 0 from right arm, and Grade 0 from right leg. This was the only incident of a detected VGE. At 76 minutes, subject reported no change in right elbow symptoms, which were localized right on the elbow, were not sensitive to touch, and were described as a mild ache. At 91 minutes, in response to a query by the test investigator, subject said that sensation in right elbow had all but disappeared. At 2nd- and 3rd-hour questioning, subject had nothing to report about his right elbow. There were no symptoms prior to descent; symptoms resolved at the test altitude of 6.5 psia.

Diagnosis: No DCS
Treatment: One-hour GLO with follow-up consultation.

Bends 9a (ambulatory control): Narratives but no DCS Assigned at JSC

11. Summary: ID# 145-04, 43-year-old male, maximum Grade 4, first VGE at 32 minutes, first report at 60 minutes, study done on n = 24, crossover dependent sample statistical design.

Procedure 18

Narrative: At 60 minutes, during 1st-hour questioning, subject reported some lightheadedness and a slight headache. Did not report initial pain score on the 1–10 scale. At 2nd-hour questioning, subject reported that headache was gone, but still lightheaded. After this entry the logbook shows, in parentheses, "not as sharp as when first entered chamber." It is not clear if this refers to lightheaded symptom. First VGE detected at 32 minutes, Grade 0 from left arm, Grade 1 from left leg, Grade 2 from right arm, and Grade 2 from right leg. Last VGE record at 175 minutes with Grade 0 from left arm, Grade 4 from left leg, Grade 1 from right arm, and Grade 4 from right leg. Subject experienced significant VGE from the start of test to the end of test. At 3rd-hour questioning, subject only reported being a little lethargic. Except for the lethargy, there

were no symptoms of headache or lightheadedness prior to descent. The logbook does not document if there were any improvements during the descent. The Questionnaire on Post-Exposure Symptoms indicated that subject experienced nausea halfway through the test.

Diagnosis: No DCS
Treatment: One-hour GLO with follow-up consultation.

Phase I PRP: Narratives but no DCS Assigned at Duke

12. Summary: ID# D980331A, 29-year-old male, maximum Grade 0, first report at 58 minutes, study done on n = 47, independent sample statistical design.

Procedure 23

Narrative: At 58 minutes and 116 minutes, subject reported unusual muscle twitches or spasms in left elbow and left forearm during flexion of the limbs for VGE measurements. Subject had no VGE. Last VGE record at 229 minutes with Grade 0 from right arm, Grade 0 from left arm, Grade 0 from left leg, and Grade 0 from right leg. There were no symptoms prior to descent; symptoms resolved at the test altitude of 4.3 psia.

Diagnosis: No DCS
Treatment: None, just self-monitoring with follow-up consultation.

13. Summary: ID# D980331B, 24-year-old male, maximum Grade 3, first VGE at 28 minutes, first report at 59 minutes, study done on n = 47, independent sample statistical design.

Procedure 23

Narrative: At 59 minutes, subject reported bilateral pain in hands extending from base of 5^{th} digit proximally along ulnar aspect to wrist and dorsally to base of thumb. Reported initial pain score of 3 on a 1–10 scale. Pain was sharp during exercise (tension-release portion of the PS/AS2 station) and dull at a pain score of 1 during rest. Symptoms lasted for approximately 105 minutes before abating to a pain score of 0. First VGE detected at 28 minutes, Grade 0 from right arm, Grade 2 from left arm, Grade 0 from left leg, and Grade 2 from right leg. Last VGE record at 232 minutes with Grade 1 from right arm, Grade 0 from left arm, Grade 0 from left leg, and Grade 0 from right leg. There were no symptoms in the hands prior to descent; symptoms resolved at the test altitude of 4.3 psia.

Diagnosis: No DCS, determined to be exercise induced; niggle?
Treatment: None, just self-monitoring with follow-up consultation.

Phase II PRP: Narratives but no DCS Assigned at Duke

14. Summary: ID# D980526B, 22-year-old male, maximum Grade 0, first report at 48 minutes, study done on n = 45, independent sample statistical design.

Procedure 24

Narrative: At 48 minutes, subject reported a dull, steady aching pain in right shin, lateral aspect. Reported initial pain score of 2 on a 1–10 scale. Subject had no VGE. Last VGE record at 233 minutes with Grade 0 from right arm, Grade 0 from left arm, Grade 0 from left leg, and Grade 0 from right leg. All symptoms were gone by 232 minutes. There were no symptoms in right shin prior to descent; symptoms resolved at the test altitude of 4.3 psia.

Diagnosis: No DCS, exercise-induced symptoms
Treatment: None, just self-monitoring with follow-up consultation.

15. Summary: ID# D980609A, 27-year-old male, maximum Grade 0, first report at 181 minutes, study done on n = 45, independent sample statistical design.

Procedure 24

Narrative: At 181 minutes, subject reported a headache but did not mention this again during the exposure. Last VGE record at 241 minutes with Grade 0 from right arm, Grade 0 from left arm, Grade 0 from left leg, and Grade 0 from right leg. During evaluation at site pressure, subject volunteered an initial pain score of 4 on a 1–10 scale for the headache, and said that it had been a steady headache. He said that the headache decreased in severity during final descent, reaching approximately a 1–2 pain score after the test.

Diagnosis: No DCS. Subject was diagnosed with idiopathic headache.
Treatment: None, just self-monitoring with follow-up consultation. Instructed to take Motrin and to rehydrate.

Phase II PRP: Narratives but no DCS Assigned at Hermann

16. Summary: ID# H980707A, 36-year-old female, maximum Grade 3, first VGE at 160 minutes, first report at 196 minutes, study done on n = 45, independent sample statistical design.

Procedure 24

Narrative: At 196 minutes, subject reported intermittent pain on antecubital side of right arm. Reported initial pain score of 2–3 on a 1–10 scale. At 212 minutes, subject reported fatigue and pain in right arm was reduced to a pain score of 1. First VGE detected at 160 minutes, Grade 0 from right arm, Grade 0 from left arm, Grade 0 from left leg, and Grade 2 from right leg. Last VGE record at 228 minutes with Grade 0 from right arm, Grade 0 from left arm, Grade 0 from left leg, and Grade 3 from right leg. Subject finished the test, but reported that the pain did not

resolve during descent. During a posttest interview by the MO, subject – while on 100% O_2 – described pain in right arm as more like an itch or a bee sting. NOTE: Subject had a hard time during the 10-minutes exercise PB, and the resistance was reduced to almost half of the prescribed amount.

Diagnosis: No DCS. The MO attributed all the symptoms to muscle strain.
Treatment: One-hour GLO with follow-up consultation.

Phase II PRP: Narratives but no DCS Assigned at DCIEM

17. Summary: ID# C980617A, 29-year-old male, maximum Grade 1, first VGE at 98 minutes, first report at 132 minutes, study done on n = 45, independent sample statistical design.

Procedure 24

Narrative: At 132 minutes, subject reported awareness in hips. Awareness persisted for the remainder of the exposure. First VGE detected at 98 minutes, Grade 0 from right arm, Grade 0 from left arm, Grade 1 from left leg, and Grade 0 from right leg. Last VGE record at 234 minutes with Grade 0 from right arm, Grade 0 from left arm, Grade 0 from left leg, and Grade 0 from right leg. Subject finished test, but no details were provided about changing symptoms in hips during descent.

Diagnosis: No DCS
Treatment: None, just self-monitoring with follow-up consultation.

18. Summary: ID# C980617C, 46-year-old male, maximum Grade 4, first VGE at 78 minutes, first report at 128 minutes, study done on n = 45, independent sample statistical design.

Procedure 24

Narrative: At 128 minutes, subject reported being suddenly tired. Fatigue was gone by 196 minutes. First VGE detected at 78 minutes, Grade 0 from right arm, Grade 0 from left arm, Grade 3 from left leg, and Grade 0 from right leg. Last VGE record at 231 minutes with Grade 1 from right arm, Grade 1 from left arm, Grade 4 from left leg, and Grade 2 from right leg. There were no symptoms prior to descent; symptoms resolved at the test altitude of 4.3 psia. NOTE: Subject had severely injured his left knee while skiing as a teenager. This was the limb with high VGE grades.

Diagnosis: No DCS
Treatment: None, just self-monitoring with follow-up consultation.

19. Summary: ID# C980625C, 46-year-old male, maximum Grade 4, first VGE at 26 minutes, first report at 90 minutes, study done on n = 45, independent sample statistical design.

Procedure 24

Narrative: At 90 minutes, subject reported that left shoulder was a bit sore, had a dull ache, which was not pain, that did not interfere with activity. Reported initial pain score of 2 on a 1–10 scale. No symptoms were present during rest but were present during activity for the rest of the exposure. First VGE detected at 26 minutes, Grade 0 from right arm, Grade 2 from left arm, Grade 1 from left leg, and Grade 2 from right leg. Last VGE record at 230 minutes with Grade 3 from right arm, Grade 3 from left arm, Grade 3 from left leg, and Grade 2 from right leg. There was questionable improvement in left shoulder on descent and during a test-of-pressure at 60 fsw for 10 minutes. On descent, he felt subjective improvement at 10.5 psia; but on questioning at site pressure, he stated that he felt there was no change during the descent.

Diagnosis: No DCS. Musculo-skeletal symptom. Had history of multiple joint symptoms.
Treatment: Trial of pressure to 60 fsw on O_2 for 10 minutes, and no change in shoulder symptom reported. Follow-up consultation the next day.

Phase III PRP: Narratives but no DCS Assigned at Duke

20. Summary: ID# D980630A, 25-year-old female, maximum Grade 2, first VGE at 79 minutes, first report at 58 minutes, study done on n = 10, independent sample statistical design.

Procedure 25

Narrative: Subject reported lower dorsal and gluteal pain during surface interval prior to final ascent to 4.3 psia. Was given a pillow to improve lower body discomfort. At 59 minutes, subject reported lower back pain during exercise and while resting. Reported initial pain score of 1 on a 1–10 scale. At 112 minutes, pain was described as pain score of 2 during sit-ups. At 162 minutes, subject complained of pain score of 5 in same region and decision was made to return her to site pressure. First VGE detected at 79 minutes, Grade 0 from right arm, Grade 1 from left arm, Grade 1 from left leg, and Grade 2 from right leg. Last VGE record at 165 minutes with Grade 0 from right arm, Grade 0 from left arm, Grade 0 from left leg, and Grade 0 from right leg. She noted immediate relief of pain with standing in chamber during lockout preparation (before recompression), with resolution to pain score 1 by arrival at surface. Posttest examination uncovered no neurological signs or symptoms.

Diagnosis: No DCS. Musculoskeletal symptom.
Treatment: One-hour GLO with follow-up consultation.

21. Summary: ID# D980707B, 29-year-old male, maximum Grade 0, first report at 108 minutes, study done on n = 10, independent sample statistical design.

Procedure 25

Narrative: At 108 minutes, subject reported dull transient pain above left eye in frontal sinus region. Reported initial pain score of 3 on a 1–10 scale. Given Afrin and monitored for remain-

der of flight. Pain score reduced to a value of 1 within 10 minutes (about 118 minutes elapsed time). Little pain (pain score of 2) was experienced during percussion test at 140 minutes. Mild sinus discomfort persisted throughout the test and during descent, with a reported pain score of 0.5–1. Subject had no VGE. Last VGE record at 221 minutes with Grade 0 from right arm, Grade 0 from left arm, Grade 0 from left leg, and Grade 0 from right leg. Final descent was paused for 30 seconds at 6.65 psia to allow subject to clear ears. Posttest examination was unremarkable except for note of mild ear barotrauma.

Diagnosis: No DCS
Treatment: None, just self-monitoring with follow-up consultation.

22. Summary: ID# D980714B, 40-year-old male, maximum Grade 0, first report at 21 minutes, study done on n = 10, independent sample statistical design.

Procedure 25

Narrative: At 21 minutes, subject reported steady tingling in right toes at rest. Reported initial pain score of 2 on a 1–10 scale. This sensation persisted for about 1 minute before it completely subsided. Subject had no VGE. Last VGE record at end of test with Grade 0 from right arm, Grade 0 from left arm, Grade 0 from left leg, and Grade 0 from right leg. There were no symptoms prior to descent; symptoms resolved at the test altitude of 4.3 psia.

Diagnosis: No DCS
Treatment: None, just self-monitoring with follow-up consultation.

Phase IV PRP: Narratives but no DCS Assigned at Duke

23. Summary: ID# D990504C, 22-year-old male, maximum Grade 0, first report at 44 minutes, study done on n = 57, independent sample statistical design.

Procedure 26

Narrative: At 44 minutes, subject reported dull, steady tingling in both legs. Reported initial pain score of 1 on a 1–10 scale. At 59 minutes, tingling was barely noticeable; a pain score of 0.5 was given, and a decision was made to remove subject due to persistence of symptom. Walking prior to lockout relieved symptoms. Subject had no VGE. Last VGE record at 40 minutes with Grade 0 from right arm, Grade 0 from left arm, Grade 0 from left leg, and Grade 0 from right leg. There were no symptoms prior to descent; symptoms resolved at the test altitude of 4.3 psia.

Diagnosis: No DCS
Treatment: None, just self-monitoring with follow-up consultation.

24. Summary: ID# D990525A, 27-year-old male, maximum Grade 0, first report at 590 minutes (10 hours from start of test), study done on n = 57, independent sample statistical design.

Procedure 26

Narrative: At 350 minutes (6 hours) after the test, subject reported pain in lower back while seated. Reported initial pain score of 2 on a 1–10 scale with a sharp pain at a pain score of 6. Subject had no VGE. Last VGE record at 228 minutes with Grade 0 from right arm, Grade 0 from left arm, Grade 0 from left leg, and Grade 0 from right leg. There were no symptoms prior to descent from 4.3 psia.

Diagnosis: No DCS. Musculoskeletal pain.
Treatment: None, just self-monitoring with follow-up consultation.

Phase IV PRP: Narratives but no DCS Assigned at DCIEM

25. Summary: ID# C990121A, 55-year-old male, maximum Grade 4, first VGE at 81 minutes, first report at 136 minutes, study done on n = 57, independent sample statistical design.

Procedure 26

Narrative: At 136 minutes, subject reported mild ambiguous symptoms (awareness) in left proximal shin. First VGE detected at 81 minutes, Grade 0 from right arm, Grade 0 from left arm, Grade 3 from left leg, and Grade 0 from right leg. Last VGE record at 233 minutes with Grade 3 from right arm, Grade 3 from left arm, Grade 4 from left leg, and Grade 4 from right leg. There were no respiratory or left and right knee symptoms prior to descent; symptoms resolved at the test altitude of 4.3 psia. NOTE: Subject had mild upper respiratory tract symptoms the following morning. This developed into a severe cold over the weekend, and he only started getting better on Wednesday.

Diagnosis: No DCS
Treatment: None, just self-monitoring with follow-up consultation.

26. Summary: ID# C990121C, 40-year-old male, maximum Grade 4, first VGE at 93 minutes, first report at 136 minutes, study done on n = 57, independent sample statistical design.

Procedure 26

Narrative: At 136 minutes, subject reported mild irritation on inspiration; suspected dry O_2. At 168 minutes, subject reported ambiguous symptoms (mild sensation) in both knees. First VGE detected at 93 minutes, Grade 0 from right arm, Grade 0 from left arm, Grade 2 from left leg, and Grade 0 from right leg. Last VGE record at 229 minutes with Grade 3 from right arm, Grade 3 from left arm, Grade 4 from left leg, and Grade 4 from right leg. There were no symptoms prior to descent; symptoms resolved at the test altitude of 4.3 psia.

Diagnosis: No DCS
Treatment: None, just self-monitoring with follow-up consultation.

27. Summary: ID# C990303D, 37-year-old male, maximum Grade 4, first VGE at 130 minutes, first report was prior to ascent to 4.3 psia, study done on n = 57, independent sample statistical design.

Procedure 26

Narrative: Subject reported generalized numbness in legs at 9.6 psia, and was told to move legs on a regular basis during the test at 4.3 psia. Numbness was attributed to the exercise cot. At 42 minutes, subject reported a sore right bicep; and at 94 minutes, he had cramps in both leg muscles. At 210 minutes, subject reported stiff legs. First VGE detected at 130 minutes, Grade 0 from right arm, Grade 0 from left arm, Grade 3 from left leg, and Grade 0 from right leg. Last VGE record at 230 minutes with Grade 2 from right arm, Grade 1 from left arm, Grade 4 from left leg, and Grade 3 from right leg. No information was provided about change in symptoms during descent to site pressure. NOTE: Subject complained of minor backache and sore leg in the morning before the PB started.

Diagnosis: No DCS
Treatment: None, just self-monitoring with follow-up consultation.

28. Summary: ID# C990324A, 53-year-old male, maximum Grade 4, first VGE at 44 minutes, first report at 112 minutes, study done on n = 57, independent sample statistical design.

Procedure 26

Narrative: At 112 minutes, subject reported slight awareness in both knees. This sensation had gone by the next Doppler measurement period (about 12 minutes). First VGE detected at 44 minutes, Grade 2 from right arm, Grade 1 from left arm, Grade 2 from left leg, and Grade 1 from right leg. Last VGE record at 232 minutes with Grade 0 from right arm, Grade 0 from left arm, Grade 3 from left leg, and Grade 3 from right leg. There were no symptoms in both knees prior to descent; symptoms resolved at the test altitude of 4.3 psia.

Diagnosis: No DCS
Treatment: None, just self-monitoring with follow-up consultation.

29. Summary: ID# C990331A, 37-year-old male, maximum Grade 4, first VGE at 82 minutes, first report at 114 minutes, study done on n = 57, independent sample statistical design.

Procedure 26

Narrative: At 114 minutes, subject reported some discomfort in right knee, possibly from sitting. At 124 minutes, subject reported a pain score of 1 on the 1–10 pain scale and definite steady discomfort for right knee. At 138 minutes, there was still steady discomfort in right knee

at a 1 on the pain score. At 154 minutes, subject reported no discomfort; symptom had completely resolved. First VGE detected at 82 minutes, Grade 0 from right arm, Grade 2 from left arm, Grade 0 from left leg, and Grade 2 from right leg. Last VGE record at 234 minutes with Grade 0 from right arm, Grade 0 from left arm, Grade 3 from left leg, and Grade 3 from right leg. There were no symptoms in right knee prior to descent; symptoms resolved at the test altitude of 4.3 psia.

Diagnosis: No DCS
Treatment: None, just self-monitoring with follow-up consultation.

30. Summary: ID# C990331C, 25-year-old female, maximum Grade 3, first VGE at 146 minutes, first report at 14 minutes, study done on n = 57, independent sample statistical design.

Procedure 26

Narrative: At 14 minutes, subject reported some tingling, but disappearing. At 130 minutes, subject reported slight tingling in back only when doing sit-ups. By 146 minutes, the tingling sensations were subsiding. First VGE detected at 146 minutes, Grade 0 from right arm, Grade 0 from left arm, Grade 2 from left leg, and Grade 0 from right leg. Last VGE record at 230 minutes with Grade 0 from right arm, Grade 0 from left arm, Grade 3 from left leg, and Grade 0 from right leg. There were no symptoms of tingling in back prior to descent; symptoms resolved at the test altitude of 4.3 psia.

Diagnosis: No DCS
Treatment: None, just self-monitoring with follow-up consultation.

31. Summary: ID# C990331D, 28-year-old female, maximum Grade 0, first report at 214 minutes, study done on n = 57, independent sample statistical design.

Procedure 26

Narrative: At 214 minutes, subject reported momentary tingling in left foot. Subject had no VGE. Last VGE record at 230 minutes with Grade 0 from right arm, Grade 0 from left arm, Grade 0 from left leg, and Grade 0 from right leg. No VGE during the run. There were no symptoms of tingling in left foot prior to descent; symptoms resolved at the test altitude of 4.3 psia.

Diagnosis: No DCS
Treatment: None, just self-monitoring with follow-up consultation.

Phase IV PRP: Narratives but no DCS Assigned at Hermann

32. Summary: ID# H990615A, 22-year-old male, maximum Grade 0, first report at 157 minutes, study done on n = 57, independent sample statistical design.

Procedure 26

Narrative: At 157 minutes, subject reported forearm numbness. Sensation improved but with a decreased sensation of an area of 2 in. × 6 in. described. Subject did not have decreased grip strength and felt fine after interview with MO. At approximately 210 minutes, subject reported bilateral forearm numbness that extended to wrists bilaterally. A decision was made to remove subject from the test. Subject had no VGE. Last VGE record at 145 minutes with Grade 0 from right arm, Grade 0 from left arm, Grade 0 from left leg, and Grade 0 from right leg. Symptoms did not resolve on return to site pressure, but numbness may have improved. On pinprick testing, bilateral forearms had decreased pinprick, as well as thenar eminence bilaterally. Soft touch was also reduced. However, muscle strength was 5/5 in all groups, and reflexes were completely normal, both upper and lower. After 15 minutes (on sea level O_2, as per protocol), subject still complained of tingling of bilateral forearms, although decreased pinprick was completely resolved. Due to persistent subjective numbness, it was decided to provide a hyperbaric treatment.

Diagnosis: No DCS. A mild case of bilateral median nerve irritation due to repetitive muscle activity was diagnosed. Due to the fact that there symptoms were bilateral, did not appear to improve in direct relation to recompression (either to sea level or at 60 fsw), and were all referable to the median nerve, it was the doctors opinion that this was not DCS, but was bilateral median nerve irritation.
Treatment: USN TT VI for possible neurological DCS, with no relief with compression to 60 fsw. After the first O_2 cycle, all subjective symptoms of tingling had resolved. This treatment was complicated by the fact that symptoms were improving when subject first entered the treatment chamber. He had no problems with TT VI, and had neither subjective nor objective neurological complaints after treatment. Follow-up consultation the next day.

Appendix A: Prebreathe and Test Details

Procedure 1 (Test 1a): A 3.5-hour O_2 PB at 14.7 psia prior to 3-hour exposure to 4.3 psia in the ETA, an altitude chamber configured to resemble the Shuttle crew compartment. Decompression required 6 minutes at 5,000 feet/minute. Exercise stressed lower body. Exercise was 4 minutes of flexing elbow and shoulder joints by rhythmically lifting a 1.36-kg weight alternately every 5 seconds from left to right hand, 4 minutes flexing hip and knee joints by rhythmically stepping on an 18.4-cm step once every 10 seconds, 4 minutes sitting or standing with no physical activity, and 4 minutes in a supine position while flexing arms and legs sequentially to improve bubble detection by DT. Each limb was flexed 3 times along with wrist and ankle rotation. Subjects used these devices from a standing or seated (non-adynamic) position and were allowed to walk during PB or altitude exposure. Test termination for DCS was after any performance was affected; but during Bends 1, the MO always stopped the test once DCS was diagnosed.

Procedure 2 (Test 1b): Twelve hours at 10.2 psia plus a 40-minutes O_2 PB prior to a 3-hour exposure to 4.3 psia in the ETA, an altitude chamber configured to resemble the Shuttle crew compartment. Decompression required 2 minutes to 10.2 psia and 4 minutes to 4.3 psia after the final PB, all at 5,000 feet/minute. Exercise stressed lower body. Gas composition at 10.2 psia was 26.5% O_2-73.5% N_2. Exercise was 4 minutes flexing elbow and shoulder joints by rhythmically lifting a 1.36-kg weight alternately every 5 seconds from left to right hand, 4 minutes flexing hip and knee joints by rhythmically stepping on an 18.4-cm step once every 10 seconds, 4 minutes sitting or standing with no physical activity, and 4 minutes in a supine position while flexing arms and legs sequentially to improve bubble detection by DT. Each limb was flexed 3 times along with wrist and ankle rotation. Subjects used these devices from a standing or seated (non-adynamic) position and were allowed to walk during PB or altitude exposure. Test termination for DCS was after any performance was affected; but during Bends 1, the MO always stopped the test once DCS was diagnosed.

Procedure 3 (Test 1c): Twelve hours at 10.2 plus a 90-minute O_2 PB prior to a 3-hour exposure to 4.3 psia in the ETA, an altitude chamber configured to resemble the Shuttle crew compartment. Decompression required 2 minutes to 10.2 psia and 4 minutes to 4.3 psia after the final PB, all at 5,000 feet/minute. Gas composition at 10.2 psia was 26.5% O_2-73.5% N_2. The exercise was 4 minutes flexing elbow and shoulder joints by rhythmically lifting a 1.36 kg-weight alternately every 5 seconds from left to right hand, 4 minutes flexing hip and knee joints by rhythmically stepping on an 18.4-cm step once every 10 seconds, 4 minutes sitting or standing with no physical activity, and 4 minutes in a supine position while flexing arms and legs sequentially to improve bubble detection by DT. Each limb was flexed 3 times along with wrist and ankle rotation. Subjects used these devices from a standing or seated (non-adynamic) position and were allowed to walk during PB or altitude exposure. Test termination for DCS was after any performance was affected; but during Bends 1. the MO always stopped the test once DCS was diagnosed.

Procedure 4 (Test 1d): Eighteen hours at 10.2 psia plus a 40-minute O_2 PB prior to a 3-hour exposure to 4.3 psia in the ETA, an altitude chamber configured to resemble the Shuttle crew

compartment. Decompression required 2 minutes to 10.2 psia and 4 minutes to 4.3 psia after the final PB, all at 5,000 feet/minute. Exercise stressed lower body. Gas composition at 10.2 psia was 26.5% O_2-73.5% N_2. The exercise was 4 minutes flexing elbow and shoulder joints by rhythmically lifting a 1.36-kg weight alternately every 5 seconds from left to right hand, 4 minutes flexing hip and knee joints by rhythmically stepping on an 18.4-cm step once every 10 seconds, 4 minutes sitting or standing with no physical activity, and 4 minutes in a supine position while flexing arms and legs sequentially to improve bubble detection by DT. Each limb was flexed 3 times along with wrist and ankle rotation. Subjects used these devices from a standing or seated (non-adynamic) position and were allowed to walk during PB or altitude exposure. Test termination for DCS was after any performance was affected; but during Bends 1, the MO always stopped the test once DCS was diagnosed.

Procedure 5 (Test 2a): A 3.5-hour O_2 PB at 14.7 prior to a 4-hour exposure to 4.3 psia in the ETA, an altitude chamber configured to resemble the Shuttle crew compartment. Decompression was gradual and allowed 30 minutes of additional O_2 PB prior to reaching 4.3 psia. The exercise stressed the upper body. "A" cycle exercise included 4 minutes seated at mini-gym set to 16.7 kg of resistance and pulling once in 5 seconds with right arm then pulling once in 5 seconds with the left arm, 4 minutes standing at ergometer set to 5-N resistance and cranking 3 times in 5 seconds with right hand going clockwise. A 5-second rest was taken, then 3 cranks repeated, 4 minutes standing at torque station 107 cm above floor where ten 3/8-in. fixed studs were torqued to 400 cm-kg. Torque was held for 5 seconds in both directions. A total of 24 separate isotonic torques were done in the 2- to 3-minute periods. Remaining time was spent stressing the wrist with a ball ratchet placed on several studs and maintaining an isotonic torque for 5 seconds. "A" cycle was to use the right hand with the ball ratchet, and finally 4 minutes in a supine position while flexing arms and legs sequentially to improve bubble detection by DT. Each limb was flexed 3 times along with wrist and ankle rotation. "B" cycle exercise included 4 minutes at mini-gym set to the same resistance as "A" cycle and pulling twice in a 5-second period, 4 minutes at ergometer using same rate except using left hand and cranking counterclockwise, 4 minutes at torque station using same torque pattern except with left hand, 4 minutes rest after completing "B" cycle, and finally 4 minutes in a supine position while flexing arms and legs sequentially to improve bubble detection by DT. Subjects used these devices from a standing or seated (non-adynamic) position and were allowed to walk during PB or altitude exposure. Test termination for DCS was after any performance was affected.

Procedure 6 (Test 2b): Twelve hours at 10.2 psia plus a 40-minute O_2 PB prior to a 4-hour exposure to 4.3 psia in the ETA, an altitude chamber configured to resemble the Shuttle crew compartment. Decompression was gradual and allowed 25 minutess of additional O_2 PB prior to reaching 4.3 psia. Exercise stressed the upper body. Gas composition at 10.2 psia was 26.5% O_2-73.5% N_2. "A" cycle exercise included 4 minutes seated at mini-gym set to 16.7 kg of resistance and pulling once in 5 seconds with right arm then pulling once in 5 seconds with the left arm, 4 minutes standing at ergometer set to 5-N resistance and cranking 3 times in 5 seconds with right hand going clockwise. A 5-second rest was taken, then 3 cranks repeated, 4 minutes standing at torque station 107 cm above floor where ten 3/8-in. fixed studs were torqued to 400 cm-kg. Torque was held for 5 seconds in both directions. A total of 24 separate isotonic torques were done in the 2- to 3-minute periods. Remaining time was spent stressing the wrist with a ball

ratchet placed on several studs and maintaining an isotonic torque for 5 seconds. "A" cycle was to use the right hand with the ball ratchet, and finally 4 minutes in a supine position while flexing arms and legs sequentially to improve bubble detection by DT. Each limb was flexed 3 times along with wrist and ankle rotation. "B" cycle exercise included 4 minutes at mini-gym set to the same resistance as "A" cycle and pulling twice in a 5-second period, 4 minutes at ergometer using same rate except using left hand and cranking counterclockwise, 4 minutes at torque station using same torque pattern except with left hand, 4 minutes rest after completing "B" cycle, and finally 4 minutes in a supine position while flexing arms and legs sequentially to improve bubble detection by DT. Subjects used these devices from a standing or seated (non-adynamic) position and were allowed to walk during PB or altitude exposure. Test termination for DCS was after any performance was affected.

Procedure 7 (Test 3a): Subject was sequestered in a trailer at JSC for about 13 hours, starting at 17:00 the day prior to the start of the test. A 4-hour O_2 PB at 14.7 psia prior to a 6-hour exposure to 4.3 psia in the ETA, an altitude chamber configured to resemble the Shuttle crew compartment. Decompression was gradual and allowed 30 minutes of additional O_2 PB prior to reaching 4.3 psia. Exercise stressed the upper body. "A" cycle exercise included 4 minutes seated at mini-gym set to 16.7 kg of resistance and pulling once in 5 seconds with right arm then pulling once in 5 seconds with the left arm, 4 minutes standing at ergometer set to 5-N resistance and cranking 3 times in 5 seconds with right hand going clockwise. A 5-second rest was taken, then 3 cranks repeated, 4 minutes standing at torque station 107 cm above floor where ten 3/8-in. fixed studs were torqued to 400 cm-kg. Torque was held for 5 seconds in both directions. A total of 24 separate isotonic torques were done in the 2- to 3-minute periods. Remaining time was spent stressing the wrist with a ball ratchet placed on several studs and maintaining an isotonic torque for 5 seconds. "A" cycle was to use the right hand with the ball ratchet, and finally 4 minutes in a supine position while flexing arms and legs sequentially to improve bubble detection by DT. Each limb was flexed 3 times along with wrist and ankle rotation. "B" cycle exercise included 4 minutes at mini-gym set to the same resistance as "A" cycle and pulling twice in a 5-second period, 4 minutes at ergometer using same rate except using left hand and cranking counterclockwise, 4 minutes at torque station using same torque pattern except with left hand, 4 minutes rest after completing "B" cycle, and finally 4 minutes in a supine position while flexing arms and legs sequentially to improve bubble detection by DT. An additional 16 minutes of rest after 3 hours of exercise was given to exercising subjects and DT due to altitude duration. Water was available only during the 6-hour chamber exposures. Subjects used these devices from a standing or seated (non-adynamic) position and were allowed to walk during PB or altitude exposure. Test termination for DCS was after any performance was affected.

Procedure 8 (Test 3b): Subject was sequestered in a trailer at JSC for about 24 hours, starting at 17:00 the day prior to the start of the test. A 60-minute O_2 PB at 14.7 psia was followed by 12 hours at 10.2 psia plus an additional 40-minute O_2 PB prior to a 6-hour exposure to 4.3 psia in the ETA, an altitude chamber configured to resemble the Shuttle crew compartment. Decompression was gradual and allowed 25 minutes of additional O_2 PB prior to reaching 4.3 psia. Exercise stressed the upper body. Gas composition at 10.2 psia was 26.5% O_2-73.5% N_2. "A" cycle exercise included 4 minutes seated at mini-gym set to 16.7 kg of resistance and pulling once in 5 seconds with right arm then pulling once in 5 seconds with the left arm, 4 minutes standing at

ergometer set to 5-N resistance and cranking 3 times in 5 seconds with right hand going clockwise. A 5-second rest was taken, then 3 cranks repeated, 4 minutes standing at torque station 107 cm above floor where ten 3/8-in. fixed studs were torqued to 400 cm-kg. Torque was held for 5 seconds in both directions. A total of 24 separate isotonic torques were done in the 2- to 3-minute periods. Remaining time was spent stressing the wrist with a ball ratchet placed on several studs and maintaining an isotonic torque for 5 seconds. "A" cycle was to use the right hand with the ball ratchet, and finally 4 minutes in a supine position while flexing arms and legs sequentially to improve bubble detection by DT. Each limb was flexed 3 times along with wrist and ankle rotation. "B" cycle exercise included 4 minutes at mini-gym set to the same resistance as "A" cycle and pulling twice in a 5-second period, 4 minutes at ergometer using same rate except using left hand and cranking counterclockwise, 4 minutes at torque station using same torque pattern except with left hand, 4 minutes rest after completing "B" cycle, and finally 4 minutes in a supine position while flexing arms and legs sequentially to improve bubble detection by DT. An additional 16 minutes of rest after 3 hours of exercise was given to exercising subjects and DT due to altitude duration. Water was available only during the 6-hour chamber exposures. Subjects used these devices from a standing or seated (non-adynamic) position and were allowed to walk during PB or altitude exposure. Test termination for DCS was after any performance was affected.

Procedure 9 (Test 3c): This was the second of 2 decompressions. A 4-hour O_2 PB at 14.7 psia prior to a 6-hour exposure to 4.3 psia in the ETA, an altitude chamber configured to resemble the Shuttle crew compartment. Decompression was gradual and allowed 30 minutes of additional O_2 PB prior to reaching 4.3 psia. Subject returned to 14.7 psia for 17 hours, a period of time spent sequestered in a trailer at JSC. The second simulated EVA began after a 4-hour O_2 PB at 14.7 psia prior to second 6-hour exposure to 4.3 psia. Decompression was gradual and allowed 30 minutes of additional O_2 PB prior to reaching 4.3 psia. Exercise stressed the upper body. "A" cycle exercise included 4 minutes seated at mini-gym set to 16.7 kg of resistance and pulling once in 5 seconds with right arm then pulling once in 5 seconds with the left arm, 4 minutes standing at ergometer set to 5-N resistance and cranking 3 times in 5 seconds with right hand going clockwise. A 5-second rest was taken, then 3 cranks repeated, 4 minutes standing at torque station 107 cm above floor where ten 3/8-in. fixed studs were torqued to 400 cm-kg. Torque was held for 5 seconds in both directions. A total of 24 separate isotonic torques were done in the 2- to 3-minute periods. Remaining time was spent stressing the wrist with a ball ratchet placed on several studs and maintaining an isotonic torque for 5 seconds. "A" cycle was to use the right hand with the ball ratchet, and finally 4 minutes in a supine position while flexing arms and legs sequentially to improve bubble detection by DT. Each limb was flexed 3 times along with wrist and ankle rotation. "B" cycle exercise included 4 minutes at mini-gym set to the same resistance as "A" cycle and pulling twice in a 5-second period, 4 minutes at ergometer using same rate except using left hand and cranking counterclockwise, 4 minutes at torque station using same torque pattern except with left hand, 4 minutes rest after completing "B" cycle, and finally 4 minutes in a supine position while flexing arms and legs sequentially to improve bubble detection by DT. An additional 16 minutes of rest after 3 hours of exercise was given to exercising subjects and DT due to the altitude duration. Water was available only during the 6-hour chamber exposures. Subjects used these devices from a standing or seated (non-adynamic) position and were allowed to walk during PB or altitude exposure. Test termination for DCS was after any performance was affected.

Procedure 10 (Test 3d): This was the second of 2 decompressions. A 60-minute O_2 PB at 14.7 psia was followed by 12 hours at 10.2 psia plus an additional 40-minute O_2 PB prior to a 6-hour exposure to 4.3 psia in the ETA, an altitude chamber configured to resemble the Shuttle crew compartment. Decompression was gradual and allowed 25 minutes of additional O_2 PB prior to reaching 4.3 psia. Subject then returned to 10.2 psia for 17 hours. Second simulated EVA began after a 40-minute O_2 PB at 10.2 psia prior to a second 6-hour exposure to 4.3 psia. Decompression was gradual and allowed 25 minutes of additional O_2 PB prior to reaching 4.3 psia. Exercise stressed the upper body. "A" cycle exercise included 4 minutes seated at mini-gym set to 16.7 kg of resistance and pulling once in 5 seconds with right arm then pulling once in 5 seconds with the left arm, 4 minutes standing at ergometer set to 5-N resistance and cranking 3 times in 5 seconds with right hand going clockwise. A 5-second rest was taken, then 3 cranks repeated, 4 minutes standing at torque station 107 cm above floor where ten 3/8-in. fixed studs were torqued to 400 cm-kg. Torque was held for 5 seconds in both directions. A total of 24 separate isotonic torques were done in the 2- to 3-minute periods. Remaining time was spent stressing the wrist with a ball ratchet placed on several studs and maintaining an isotonic torque for 5 seconds. "A" cycle was to use the right hand with the ball ratchet, and finally 4 minutes in a supine position while flexing arms and legs sequentially to improve bubble detection by DT. Each limb was flexed 3 times along with wrist and ankle rotation. "B" cycle exercise included 4 minutes at mini-gym set to the same resistance as "A" cycle and pulling twice in a 5-second period, 4 minutes at ergometer using same rate except using left hand and cranking counterclockwise, 4 minutes at torque station using same torque pattern except with left hand, 4 minutes rest after completing "B" cycle, and finally 4 minutes in a supine position while flexing arms and legs sequentially to improve bubble detection by DT. An additional 16 minutes of rest after 3 hours of exercise was given to exercising subjects and DT due to the altitude duration. Water was available only during the 6-hour chamber exposures. Subjects used these devices from a standing or seated (non-adynamic) position and were allowed to walk during PB or altitude exposure. Test termination for DCS was after any performance was affected.

Procedure 11 (Test 4a): A 60-minute O_2 PB at 14.7 psia was followed by 12 hours at 10.2 psia plus an additional 40-minute O_2 PB prior to a 3-hour exposure to 4.3 psia in the ETA, an altitude chamber configured to resemble the Shuttle crew compartment. This was the first of 2 exposures in the same day. Decompression was gradual and allowed 20 minutes of additional O_2 PB prior to reaching 4.3 psia. Gas composition at 10.2 psia was 26.5% O_2-73.5% N_2. Decompression from 14.7 to 10.2 psia required 20 minutes. Exercise stressed the upper body. "A" cycle exercise included 4 minutes seated at mini-gym set to 16.7 kg of resistance and pulling once in 5 seconds with right arm then pulling once in 5 seconds with the left arm, 4 minutes standing at ergometer set to 5-N resistance and cranking 3 times in 5 seconds with right hand going clockwise. A 5-second rest was taken, then 3 cranks repeated, 4 minutes standing at torque station 107 cm above floor where ten 3/8-in. fixed studs were torqued to 400 cm-kg. Torque was held for 5 seconds in both directions. A total of 24 separate isotonic torques were done in the 2- to 3-minute periods. Remaining time was spent stressing the wrist with a ball ratchet placed on several studs and maintaining an isotonic torque for 5 seconds. "A" cycle was to use the right hand with the ball ratchet, and finally 4 minutes in a supine position while flexing arms and legs sequentially to improve bubble detection by DT. Each limb was flexed 3 times along with wrist and ankle rotation. "B" cycle exercise included 4 minutes at mini-gym set to the same resistance as "A" cycle and pulling twice in a 5-second period, 4 minutes at ergometer using same rate except

using left hand and cranking counterclockwise, 4 minutes at torque station using same torque pattern except with left hand, 4 minutes rest after completing "B" cycle, and finally 4 minutes in a supine position while flexing arms and legs sequentially to improve bubble detection by DT. Subjects used these devices from a standing or seated (non-adynamic) position and were allowed to walk during PB or altitude exposure. Test termination for DCS was after any performance was affected.

Procedure 12 (Test 5a): A 6-hour O_2 PB at 14.7 psia prior to a 6-hour exposure to 4.3 psia in the PTC. Prior to ascent, a brief ear and sinus check was done by depressurizing the chamber atmosphere to the equivalent of 6,000 feet altitude in approximately 1 minute (5,000 feet/minute). Subject continued to breathe O_2 by mask during this check, which took about 5 minutes for subjects and DT to be evaluated, primarily during the repressurization back to site pressure. The medical technician exited the chamber, and ascent to the test altitude was initiated. Decompression required 15 minutes. Exercise stressed upper body. "A" cycle exercise included 4 minutes seated at mini-gym set to 16.7 kg of resistance and pulling once in 5 seconds with right arm then pulling once in 5 seconds with the left arm, 4 minutes standing at ergometer set to 5-N resistance and cranking 3 times in 5 seconds with right hand going clockwise. A 5-second rest was taken, then 3 cranks repeated, 4 minutes standing at torque station 107 cm above floor where ten 3/8-in. fixed studs were torqued to 400 cm-kg. Torque was held for 5 seconds in both directions. A total of 24 separate isotonic torques were done in the 2- to 3-minute periods. Remaining time was spent stressing the wrist with a ball ratchet placed on several studs and maintaining an isotonic torque for 5 seconds. "A" cycle was to use the right hand with the ball ratchet, and finally 4 minutes in a supine position while flexing arms and legs sequentially to improve bubble detection by DT. Each limb was flexed 3 times along with wrist and ankle rotation. "B" cycle exercise included 4 minutes at mini-gym set to the same resistance as "A" cycle and pulling twice in a 5-second period, 4 minutes at ergometer using same rate except using left hand and cranking counterclockwise, 4 minutes at torque station using same torque pattern except with left hand, 4 minutes rest after completing "B" cycle, and finally 4 minutes in a supine position while flexing arms and legs sequentially to improve bubble detection by DT. An additional 16 minutes of rest after 3 hours of exercise was given to exercising subjects and DT due to altitude duration. Water was available only during the 6-hour chamber exposures. Subjects used these devices from a standing or seated (non-adynamic) position and were allowed to walk during PB or altitude exposure. Test termination for DCS was after any performance was affected.

Procedure 13 (Test 6): A 2-hour O_2 PB at 14.7 psia prior to 24 hours at 10.2 psia in the ETA, an altitude chamber configured to resemble the Shuttle crew compartment. A 15-minute decompression from 14.7 psia to 10.2 psia was included as a portion of the 2-hour O_2 PB. Ten minutes' decompression from 10.2 psia to 6.0 psia after 24 hours. Subjects exercised 6 hours while breathing a 60% O_2-40% N_2 mixture. Exercise stressed upper body. Gas composition at 10.2 psia was 28% O_2-72% N_2. "A" cycle exercise included 4 minutes seated at mini-gym set to 16.7 kg of resistance and pulling once in 5 seconds with right arm then pulling once in 5 seconds with the left arm, 4 minutes standing at ergometer set to 5-N resistance and cranking 3 times in 5 seconds with right hand going clockwise. A 5-second rest was taken, then 3 cranks repeated, 4 minutes standing at torque station 107 cm above floor where ten 3/8-in. fixed studs were torqued

to 400 cm-kg. Torque was held for 5 seconds in both directions. A total of 24 separate isotonic torques were done in the 2- to 3-minute periods. Remaining time was spent stressing the wrist with a ball ratchet placed on several studs and maintaining an isotonic torque for 5 seconds. "A" cycle was to use the right hand with the ball ratchet, and finally 4 minutes in a supine position while flexing arms and legs sequentially to improve bubble detection by DT. Each limb was flexed 3 times along with wrist and ankle rotation. "B" cycle exercise included 4 minutes at mini-gym set to the same resistance as "A" cycle and pulling twice in a 5-second period, 4 minutes at ergometer using same rate except using left hand and cranking counterclockwise, 4 minutes at torque station using same torque pattern except with left hand, 4 minutes rest after completing "B" cycle, and finally 4 minutes in a supine position while flexing arms and legs sequentially to improve bubble detection by DT. An additional 16 minutes of rest after 3 hours of exercise was given to exercising subjects and DT due to altitude duration. Water was available only during the 6-hour chamber exposures. Subjects used these devices from a standing or seated (non-adynamic) position and were allowed to walk during PB or altitude exposure. Test termination for DCS was after any performance was affected.

Procedure 14 (Test 7 with high exercise): Exposure to 6.5 psia in the PTC for 3 hours after no PB. Decompression to 6.5 psia required 3 minutes (6,500 feet/minute). Row machine replaced the standard mini-gym and was used to achieve peak exercise of 2,000 Btu/hour for 15 minutes at about 1.5 hours into the test. Prior to ascent, a brief ear and sinus check was done by depressurizing the chamber atmosphere to the equivalent of 6,000 feet altitude in approximately 1 minute (5,000 feet/minute). Subject breathed air during this check, which took approximately 5 minutes for 2 subjects and the DT to be evaluated, primarily during the repressurization back to site pressure. The medical technician exited the chamber and an ascent on air to 10 psia at 6,500 feet/minute was begun 6 minutes from the start of initial ascent. About 2 minutes later, subject donned the O_2 mask at 10 psia and the chamber continued ascent to 6.5 psia at 6,500 feet/minute. For the first hour, "A" cycle exercise included 4 minutes standing at ergometer set to 5-N resistance and cranking 3 times in 5 seconds with right hand going clockwise. A 5-second rest was taken, and then 3 cranks repeated. There were 4 minutes standing at torque station above the floor where ten 3/8-in. fixed studs were torqued to 400 cm-kg with the right hand. Torque was held for 5 seconds in both directions. There were 4 minutes in a supine position while flexing arms and legs sequentially to improve bubble detection by DT. Each limb was flexed 3 times along with wrist and ankle rotation. There were 4 minutes in a semi-recumbent position on a row machine where upper and lower body was exercised. Cycle "B" exercise was the same as cycle "A" except the left hand was used with the torque and crank stations. At 64 minutes into the test, subject exercised for three 16-minute periods on the row machine, with a 4-minute Doppler monitoring at the end of each 16-minute cycle. The middle row exercise achieved about 2,000 Btu/hour while the previous and later 16-minute intervals achieved about 1,600 Btu/hour. For the last hour, the same cycle "A" and "B" exercises resumed. Subjects used these devices from a standing or seated (non-adynamic) position and were allowed to walk prior to ascent or during altitude exposure. Test termination for DCS was after any performance was affected.

Procedure 15 (Test 7 with low exercise): Exposure to 6.5 psia in the PTC for 3 hours after no PB. Decompression to 6.5 psia required 3 minutes (6,500 feet/minute). Row machine used in place of the standard mini-gym to achieve an average energy expenditure of 800 Btu/hour. Prior

to ascent, a brief ear and sinus check was done by depressurizing the chamber atmosphere to the equivalent of 6,000 feet altitude in about 1 minute (5,000 feet/minute). Subject breathed air during this check, which took approximately 5 minutes for 2 subjects and the DT to be evaluated, primarily during the repressurization back to site pressure. The medical technician exited the chamber and an ascent on air to 10 psia at 6,500 feet/minute was begun 6 minutes from the start of initial ascent. About 2 minutes later, subject donned the O_2 mask at 10 psia and the chamber continued the ascent to 6.5 psia at 6,500 feet/minute. "A" cycle exercise included 4 minutes standing at ergometer set to 5-N resistance and cranking 3 times in 5 seconds with right hand going clockwise. A 5-second rest was taken, and then 3 cranks repeated. There were 4 minutes standing at torque station above the floor where ten 3/8-in. fixed studs were torqued to 400 cm-kg with the right hand. Torque was held for 5 seconds in both directions. There were 4 minutes in a supine position while flexing arms and legs sequentially to improve bubble detection by DT. Each limb was flexed 3 times along with wrist and ankle rotation. There were 4 minutes in a semi-recumbent position on a row machine where upper and lower body was exercised. Cycle "B" exercise was the same as cycle "A" except the left hand was used with the torque and crank stations. Subjects used these devices from a standing or seated (non-adynamic) position and were allowed to walk prior to ascent or during altitude exposure. Test termination for DCS was after any performance was affected.

Procedure 16 (Test 8a): Exposure to 6.5 psia in the PTC for 3 hours after no PB. Decompression to 6.5 psia required 3 minutes (6,500 feet/minute). Prior to ascent, a brief ear and sinus check was done by depressurizing the chamber atmosphere to the equivalent of 6,000 feet altitude in about 1 minute (5,000 feet/minute). Subject breathed air during this check, which took approximately 5 minutes for subjects and the DT to be evaluated, primarily during the repressurization back to site pressure. The medical technician exited the chamber and an ascent on air to 10 psia at 6,500 feet/minute was begun 6 minutes from the start of initial ascent. Approximately 2 minutes later, subject donned the O_2 mask at 10 psia and the chamber continued the ascent to 6.5 psia at 6,500 feet/minute. Exercise stressed the upper body. "A" cycle exercise included 4 minutes seated at mini-gym set to 16.7 kg of resistance and pulling once in 5 seconds with right arm then pulling once in 5 seconds with the left arm, 4 minutes standing at ergometer set to 5-N resistance and cranking 3 times in 5 seconds with right hand going clockwise. A 5-second rest was taken, then 3 cranks repeated, 4 minutes standing at torque station where ten 3/8-in. fixed studs were torqued to 400 cm-kg. Torque was held for 5 seconds in both directions. A total of 24 separate isotonic torques were done in the 2- to 3-minute periods. Remaining time was spent stressing the wrist with a ball ratchet placed on several studs and maintaining an isotonic torque for 5 seconds. "A" cycle was to use the right hand with the ball ratchet, and finally 4 minutes in a supine position while flexing arms and legs sequentially to improve bubble detection by DT. Each limb was flexed 3 times along with wrist and ankle rotation. "B" cycle exercise included 4 minutes at mini-gym set to the same resistance as "A" cycle and pulling twice in a 5-second period, 4 minutes at ergometer using same rate except using left hand and cranking counterclockwise, 4 minutes at torque station using same torque pattern except with left hand, 4 minutes rest after completing "B" cycle, and finally 4 minutes in a supine position while flexing arms and legs sequentially to improve bubble detection by DT. Subjects used these devices from a standing or seated (non-adynamic) position and were allowed to walk during PB or altitude exposure. Test termination for DCS was after any performance was affected. A 1-hour posttest period

breathing 100% O_2 for all subjects was observed, with longer periods as warranted at the direction of the attending MO.

Procedure 17 (Test 8b): Exposure to 6.5 psia in the PTC for 3 hours after no PB. Decompression to 6.5 psia required 3 minutes (6,500 feet/minute). Prior to ascent, a brief ear and sinus check was done by depressurizing the chamber atmosphere to the equivalent of 6,000 feet altitude in approximately 1 minute (5,000 feet/minute). Subject breathed air during this check, which took about 5 minutes for subjects and the DT to be evaluated, primarily during the repressurization back to site pressure. The medical technician exited the chamber and an ascent on air to 10 psia at 6,500 feet/minute was begun 6 minutes from the start of the initial ascent. About 2 minutes later, subject donned the O_2 mask at 10 psia and the chamber continued the ascent to 6.5 psia at 6,500 feet/minute. Prior to exposure, subject performed 3 days of treadmill exercise at anaerobic threshold for 30 minutes. A minimum of 16 hours elapsed from the last treadmill exercise to the start of ascent. Exercise at 6.5 psia stressed the upper body. "A" cycle exercise included 4 minutes seated at mini-gym set to 16.7 kg of resistance and pulling once in 5 seconds with right arm then pulling once in 5 seconds with the left arm, 4 minutes standing at ergometer set to 5-N resistance and cranking 3 times in 5 seconds with right hand going clockwise. A 5-second rest was taken, then 3 cranks repeated, 4 minutes standing at torque station where ten 3/8-in. fixed studs were torqued to 400 cm-kg. Torque was held for 5 seconds in both directions. A total of 24 separate isotonic torques were done in the 2- to 3-minute periods. Remaining time was spent stressing the wrist with a ball ratchet placed on several studs and maintaining an isotonic torque for 5 seconds. "A" cycle was to use the right hand with the ball ratchet, and finally 4 minutes in a supine position while flexing arms and legs sequentially to improve bubble detection by DT. Each limb was flexed 3 times along with wrist and ankle rotation. "B" cycle exercise included 4 minutes at mini-gym set to the same resistance as "A" cycle and pulling twice in a 5-second period, 4 minutes at ergometer using same rate except using left hand and cranking counterclockwise, 4 minutes at torque station using same torque pattern except with left hand, 4 minutes rest after completing "B" cycle, and finally 4 minutes in a supine position while flexing arms and legs sequentially to improve bubble detection by DT. Subjects used these devices from a standing or seated (non-adynamic) position and were allowed to walk during PB or altitude exposure. Test termination for DCS was after any performance was affected. A 1-hour posttest period breathing 100% O_2 for all subjects was observed, with longer periods as warranted at the direction of the attending MO.

Procedure 18 (Test 9a): Exposure to 6.5 psia in the PTC for 3 hours after no PB. Decompression to 6.5 psia required 3 minutes (6,500 feet/minute). Prior to ascent, a brief ear and sinus check was done by depressurizing the chamber atmosphere to the equivalent of 6,000 feet altitude in about 1 minute (5,000 feet/minute). Subject breathed air during this check, which took approximately 5 minutes for subjects and the DT to be evaluated, primarily during the repressurization back to site pressure. The medical technician exited the chamber and an ascent on air to 10 psia at 6,500 feet/minute was begun 6 minutes from the start of initial ascent. About 2 minutes later, subject donned the O_2 mask at 10 psia and the chamber continued the ascent to 6.5 psia at 6,500 feet/minute. Exercise stressed the upper body. "A" cycle exercise included 4 minutes seated at mini-gym set to 16.7 kg of resistance and pulling once in 5 seconds with right arm then pulling once in 5 seconds with the left arm, 4 minutes standing at ergometer set to 5-N resistance

and cranking 3 times in 5 seconds with right hand going clockwise. A 5-second rest was taken, then 3 cranks repeated, 4 minutes standing at torque station where ten 3/8-in. fixed studs were torqued to 400 cm-kg. Torque was held for 5 seconds in both directions. A total of 24 separate isotonic torques were done in the 2- to 3-minute periods. The remaining time was spent stressing the wrist with a ball ratchet placed on several studs and maintaining an isotonic torque for 5 seconds. "A" cycle was to use the right hand with the ball ratchet, and finally 4 minutes in a supine position while flexing arms and legs sequentially to improve bubble detection by DT. Each limb was flexed 3 times along with wrist and ankle rotation. "B" cycle exercise included 4 minutes at mini-gym set to the same resistance as "A" cycle and pulling twice in a 5-second period, 4 minutes at ergometer using same rate except using left hand and cranking counterclockwise, 4 minutes at torque station using same torque pattern except with left hand, 4 minutes rest after completing "B" cycle, and finally 4 minutes in a supine position while flexing arms and legs sequentially to improve bubble detection by DT. Subjects used these devices from a standing or seated (non-adynamic) position and were allowed to walk prior to and during altitude exposure. Test termination for DCS was after any performance was affected.

Procedure 19 (Test 9b): Three days prior to ascent, subject was maintained in strict bed rest in a 6-degree head-down tilt. Exposure to 6.5 psia in the PTC for 3 hours after no PB. Decompression to 6.5 psia required 3 minutes (6,500 feet/minute). Prior to ascent, a brief ear and sinus check was done by depressurizing the chamber atmosphere to the equivalent of 6,000 feet altitude in about 1 minute (5,000 feet/minute). Subject breathed air during this check, which took approximately 5 minutes for subjects and the DT to be evaluated, primarily during the repressurization back to site pressure. The medical technician exited the chamber and an ascent on air to 10 psia at 6,500 feet/minute was begun 6 minutes from the start of initial ascent. About 2 minutes later, subject donned the O_2 mask at 10 psia and the chamber continued the ascent to 6.5 psia at 6,500 feet/minute. Exercise stressed upper body and was performed while still in a 6-degree head-down tilt. "A" cycle exercise included 4 minutes at mini-gym set to 16.7 kg of resistance and pulling once in 5 seconds with right arm then pulling once in 5 seconds with the left arm, 4 minutes at ergometer set to 5-N resistance and cranking 3 times in 5 seconds with right hand going clockwise. A 5-second rest was taken, then 3 cranks repeated, 4 minutes at torque station where ten 3/8-in. fixed studs were torqued to 400 cm-kg. Torque was held for 5 seconds in both directions. A total of 24 separate isotonic torques were done in the 2- to 3-minute periods. Remaining time was spent stressing the wrist with a ball ratchet placed on several studs and maintaining an isotonic torque for 5 seconds. "A" cycle was to use the right hand with the ball ratchet, and finally 4 minutes in a 6-degree head-down position while flexing arms and legs sequentially to improve bubble detection by DT. Each limb was flexed 3 times along with wrist and ankle rotation. "B" cycle exercise included 4 minutes at mini-gym set to the same resistance as "A" cycle and pulling twice in a 5-second period, 4 minutes at ergometer using same rate except using left hand and cranking counterclockwise, 4 minutes at torque station using same torque pattern except with left hand, 4 minutes rest after completing "B" cycle, and finally 4 minutes in a supine position while flexing arms and legs sequentially to improve bubble detection by DT. Subjects used these devices from a recumbent (adynamic) position and were not allowed to walk prior to or during altitude exposure. Test termination for DCS was after any performance was affected.

Procedure 20 (Test 9c): A 4-hour O_2 PB at 14.7 psia prior to a 3-hour exposure to 4.3 psia in the PTC. Prior to ascent, a brief ear and sinus check was done by depressurizing the chamber atmosphere to the equivalent of 6,000 feet altitude in about 1 minute (5,000 feet/minute). Subject breathed O_2 during this check, which took approximately 5 minutes for subjects and the DT to be evaluated, primarily during the repressurization back to site pressure. The medical technician exited the chamber before the ascent to 4.3 psia at 5,000 feet/minute. Ascent was 6 minutes to 4.3 psia. Exercise stressed the upper body. "A" cycle exercise included 4 minutes seated at mini-gym set to 16.7 kg of resistance and pulling once in 5 seconds with right arm then pulling once in 5 seconds with the left arm, 4 minutes standing at ergometer set to 5-N resistance and cranking 3 times in 5 seconds with right hand going clockwise. A 5-second rest was taken, then 3 cranks repeated, 4 minutes standing at torque station where ten 3/8-in. fixed studs were torqued to 400 cm-kg. Torque was held for 5 seconds in both directions. A total of 24 separate isotonic torques were done in the 2- to 3-minute periods. Remaining time was spent stressing the wrist with a ball ratchet placed on several studs and maintaining an isotonic torque for 5 seconds. "A" cycle was to use the right hand with the ball ratchet, and finally 4 minutes in a supine position while flexing arms and legs sequentially to improve bubble detection by DT. Each limb was flexed 3 times along with wrist and ankle rotation. "B" cycle exercise included 4 minutes at mini-gym set to the same resistance as "A" cycle and pulling twice in a 5-second period, 4 minutes at ergometer using the same rate except using left hand and cranking counterclockwise, 4 minutes at torque station using the same torque pattern except with left hand, 4 minutes rest after completing "B" cycle, and finally 4 minutes in a supine position while flexing arms and legs sequentially to improve bubble detection by DT. Subjects used these devices from a standing or seated (non-adynamic) position and were allowed to walk prior to and during altitude exposure. Test termination for DCS was after any performance was affected.

Procedure 21 (Test 10): Subjects exercised while breathing air at a simulated depth of 20 feet in a hyperbaric chamber. A 1-minute compression to 1.59 ATA in the Hyperbaric Treatment Chamber (20 feet fresh water depth), 400-minute exposed to air while performing three 4-minute exercises with a 4-minutes period of rest. The exercise consisted of right arm ergometry from a standing position at a rate of 10 rev clockwise per 5 seconds against a weight of 6 lbs with a rest period of 5 seconds before starting left arm ergometry with a counterclockwise rotation, lifting a 3-lb weight in each hand while performing a step test, and 4 minutes standing at torque station where ten 3/8-in. fixed studs were torqued to 400 cm-kg. Torque was held for 5 seconds in both directions. A total of 24 separate isotonic torques were done in the 2- to 3-minute periods. Remaining time was spent stressing the wrist with a ball ratchet placed on several studs and maintaining an isotonic torque for 5 seconds. "A" cycle was to use the right hand and "B" cycle was to use the left hand. Cycles are repeated for 400 minutes with a 4-minute rest every 30 minutes and an 8-minute rest every hour. Ascent to site pressure was made in 1 minute; 14 hours elapsed before a 2-minute ascent to 10.1 psia (10,000 feet altitude) in the PTC. Subject breathed air at 10,000 feet and did no exercise during the 3-hour exposure. Doppler monitoring performed for 4 minutes after 16 minutes of exercise for the duration of exposure. Subjects used the exercise devices at 1.59 ATA from a standing (non-adynamic) position and were allowed to walk during the surface interval and altitude exposure. Test termination for DCS was after any performance was affected.

Procedure 22 (Test 11): A 3-hour O_2 PB at 14.7 psia prior to a 4-hour exposure to 4.3 psia in the PTC. Prior to ascent, a brief ear and sinus check was done by depressurizing the chamber atmosphere to the equivalent of 6,000 feet altitude in about 1 minute (5,000 feet/minute). Subject breathed O_2 during this check, which took approximately 5 minutes for subjects and the DT to be evaluated, primarily during repressurization back to site pressure. The medical technician exited the chamber before the ascent to 4.3 psia at 5,000 feet/minute. Ascent was 6 minutes to 4.3 psia. Exercise stressed the upper body. "A" cycle exercise included 4 minutes seated at mini-gym set to 16.7 kg of resistance and pulling once in 5 seconds with right arm then pulling once in 5 seconds with the left arm, 4 minutes seated at ergometer set to 5-N resistance and cranking 3 times in 5 seconds with right hand going clockwise. A 5-second rest was taken, then 3 cranks repeated, 4 minutes seated at torque station where ten 3/8-in. fixed studs were torqued to 400 cm-kg. Torque was held for 5 seconds in both directions. A total of 24 separate isotonic torques were done in the 2- to 3-minute periods. Remaining time was spent stressing the wrist with a ball ratchet placed on several studs and maintaining an isotonic torque for 5 seconds. "A" cycle was to use the right hand with the ball ratchet, and finally 4 minutes in a supine position while flexing arms and legs sequentially to improve bubble detection by DT. Each limb was flexed 3 times along with wrist and ankle rotation. "B" cycle exercise included 4 minutes at mini-gym set to the same resistance as "A" cycle and pulling twice in a 5-second period, 4 minutes at ergometer using same rate except using left hand and cranking counterclockwise, 4 minutes at torque station using same torque pattern except with left hand, 4 minutes rest after completing "B" cycle, and finally 4 minutes in a seated position while flexing arms and legs sequentially to improve bubble detection by DT. Subjects used these devices from a seated (adynamic) position and were not allowed to walk during PB or altitude exposure. Test termination for DCS was at first indication of DCS.

Procedure 23 (Phase I PRP): PB exercise was 10 minutes of dual-cycle arm and leg ergometery initiated at the start of PB, and done at 75% of peak O_2 consumption for the last 7 minutes. No additional exercise was allowed for the balance of the 150-minute O_2 PB. After 50 minutes of 100% O_2 PB at site pressure, subject ascended to 9.6 psia in 20 minutes followed by a 10-minute descent to 10.2 psia, still breathing 100% O_2. The gas supply was switched in the mask, and subject breathed 73.5% N_2 and 26.5% O_2 for 30 minutes while at 10.2 psia. A 100% O_2 PB was reestablished and, after 5 minutes, a descent to site pressure was performed. Subject remained on 100% O_2 for 35 minutes at site pressure and during the 30-minute ascent to 4.3 psia. Subject breathed 100% O_2 for the duration of the 4-hour test. Five exercise devices simulated intense hand and upper body activity plus postural contractions in the lower body that occur during EVA. Two bungee cord devices simulated the resistance to move a flexible spacesuit from an otherwise neutral position. Subjects pulled bungee cord with left and right arm across the chest, and flexed the upper body forward against the bungee cord connected to the back of a harness. Three other devices simulated assembly tasks done while in a spacesuit. Subjects torqued fixed studs to 25 ft-lb with the right and left arm, contracted the right and left hand with 5-lb of force using a hand exercise device, and pulled against a plate at their feet with leg muscles contracted to resist the pull to a force in lbs normalized to their body weight. Subjects used these devices from a recumbent (adynamic) position and were not allowed to walk during PB or altitude exposure. Each activity was 4 minutes in duration and performed at a 5- or 10-second cadence with brief periods of rest during some activities. There were also 4-minute periods with no physical activity, and 4 minutes in a supine position while flexing arms and legs sequentially

to improve bubble detection by DT. Each limb was flexed 3 times along with wrist and ankle rotation. Test termination for DCS was at first indication of DCS.

Procedure 24 (Phase II PRP): PB exercise was 10 minutes of dual-cycle arm and leg ergometery initiated at the start of PB, and done at 75% of peak O_2 consumption for the last 7 minutes plus 24 minutes of additional intermittent light arm and leg exercise starting 55 minutes into the PB and ending 95 minutes after the start of PB. Here, heavy short-duration ergometry exercise was combined with light intermittent short-duration exercise during the later part of the PB. After 50 minutes of 100% O_2 PB at site pressure, subject ascended to 9.6 psia in 20 minutes followed by a 10-minute descent to 10.2 psia, still breathing 100% O_2. After the gas supply was switched in the mask, the subject breathed 73.5% N_2 and 26.5% O_2 for 30 minutes while at 10.2 psia. A 100% O_2 PB was reestablished and, after 5 minutes, a descent to site pressure was performed. Subject remained on 100% O_2 for 35 minutes at site pressure and during the 30-minute ascent to 4.3 psia. Subject breathed 100% O_2 for the duration of the 4-hour test. Five exercise devices simulated intense hand and upper body activity plus postural contractions in the lower body that occur during EVA. Two bungee cord devices simulated the resistance to move a flexible spacesuit from an otherwise neutral position. Subjects pulled bungee cord with left and right arm across the chest, and flexed the upper body forward against the bungee cord connected to the back of a harness. Three other devices simulated assembly tasks done while in a spacesuit. Subjects torqued fixed studs to 25 ft-lb with the right and left arm, contracted the right and left hand with 5-lb of force using a hand exercise device, and pulled against a plate at their feet with leg muscles contracted to resist the pull to a force in lbs normalized to their body weight. Subjects used these devices from a recumbent (adynamic) position and were not allowed to walk during PB or altitude exposure. Each activity was 4 minutes in duration and performed at a 5- or 10-second cadence with brief periods of rest during some activities. There were also 4-minute periods with no physical activity, and 4 minutes in a supine position while flexing arms and legs sequentially to improve bubble detection by DT. Each limb was flexed 3 times along with wrist and ankle rotation. Test termination for DCS was at first indication of DCS.

Procedure 25 (Phase III PRP): PB exercise was 24 minutes of intermittent light arm and leg exercise starting 55 minutes into the PB and ending 95 minutes after the start of PB. After 50 minutes of 100% O_2 PB at site pressure, subject ascended to 9.6 psia in 20 minutes followed by a 10-minute descent to 10.2 psia, still breathing 100% O_2. The gas supply was switched in the mask, and subject breathed 73.5% N_2 and 26.5% O_2 for 30 minutes while at 10.2 psia. A 100% O_2 PB was reestablished and, after 5 minutes, a descent to site pressure was performed. Subject remained on 100% O_2 for 35 minutes at site pressure and during the 30-minute ascent to 4.3 psia. Subject breathed 100% O_2 for the duration of the 4-hour test. Five exercise devices simulated intense hand and upper body activity plus postural contractions in the lower body that occur during EVA. Two bungee cord devices simulated the resistance to move a flexible spacesuit from an otherwise neutral position. Subjects pulled bungee cord with left and right arm across the chest, and flexed the upper body forward against the bungee cord connected to the back of a harness. Three other devices simulated assembly tasks done while in a spacesuit. Subjects torqued fixed studs to 25 ft-lb with the right and left arm, contracted the right and left hand with 5-lb of force using a hand exercise device, and pulled against a plate at their feet with leg muscles contracted to resist the pull to a force in lbs normalized to their body weight. Subjects used these devices

from a recumbent (adynamic) position and were not allowed to walk during PB or altitude exposure. Each activity was 4 minutes in duration and performed at a 5- or 10-second cadence with brief periods of rest during some activities. There were also 4-minute periods with no physical activity, and 4 minutes in a supine position while flexing arms and legs sequentially to improve bubble detection by DT. Each limb was flexed 3 times along with wrist and ankle rotation. Test termination for DCS was at first indication of DCS.

Procedure 26 (Phase IV PRP): PB exercise was 56 minutes of intermittent light long-duration arm and leg exercise that started 4 minutes into the PB and ended 95 minutes from the start of the PB. After 50 minutes of 100% O_2 PB at site pressure, subject ascended to 9.6 psia in 20 minutes followed by a 10-minute descent to 10.2 psia, still breathing 100% O_2. The gas supply was switched in the mask, and subject breathed 73.5% N_2 and 26.5% O_2 for 30 minutes while at 10.2 psia. A 100% O_2 PB was reestablished and, after 5 minutes, a descent to site pressure was performed. Subject remained on 100% O_2 for 35 minutes at site pressure and during a 30-minute ascent to 4.3 psia. Subject breathed 100% O_2 for the duration of the 4-hour test. Five exercise devices simulated intense hand and upper body activity plus postural contractions in the lower body that occur during EVA. Two bungee cord devices simulated the resistance to move a flexible spacesuit from an otherwise neutral position. Subjects pulled bungee cord with left and right arm across the chest, and flexed the upper body forward against the bungee cord connected to the back of a harness. Three other devices simulated assembly tasks done while in a spacesuit. Subjects torqued fixed studs to 25 ft-lb with the right and left arm, contracted the right and left hand with 5-lb of force using a hand exercise device, and pulled against a plate at their feet with leg muscles contracted to resist the pull to a force in lbs normalized to their body weight. Subjects used these devices from a recumbent (adynamic) position and were not allowed to walk during PB or altitude exposure. Each activity was 4 minutes in duration and performed at a 5- or 10-second cadence with brief periods of rest during some activities. There were also 4-minute periods with no physical activity, and 4 minutes in a supine position while flexing arms and legs sequentially to improve bubble detection by DT. Each limb was flexed 3 times along with wrist and ankle rotation. Test termination for DCS was at first indication of DCS.

Appendix B: Summary of JSC Information about Patent Foramen Ovale

The Incidence of Patent Foramen Ovale and Serious Symptoms of Decompression Sickness in Trials Conducted to Develop Operational Decompression Prevention Protocols for Space Flight

Study conducted in the Environmental Physiology and Cardiovascular Laboratories
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Abstract

In the course of conducting research on decompression protocols to minimize the risk of decompression sickness (DCS) during extravehicular activities (EVA), 5 instances of Type II symptoms have been encountered. Three of these individuals were tested retrospectively for the presence of a Patent Foramen Ovale (PFO) utilizing transthoracic echocardiography with saline contrast. Two of the 3 were positive for PFO at rest without a Valsalva maneuver. In a separate group of 42 subjects tested prospectively, a PFO was detected in 21%of these subjects at rest and in 26% of these subjects when a Valsalva maneuver was performed.

Introduction

The shuttle spacecraft utilizes a normal cabin pressure of 14.7 psia while the pressure suit used to conduct EVA operates at a 4.3 psia. This change in pressure would be sufficient to cause frequent and severe DCS if nothing were done to prevent it. A number of trials of protocols to prevent DCS have been conducted over the years by the Environmental Physiology Laboratory at the Johnson Space Center (JSC) (*1-9*). These trials and trials sponsored at Air Force and university laboratories (*10-12*) have led to DCS prevention protocols that have been used without an incident of DCS on over 150 EVAs. In the conduct of these trials at JSC, a database has accumulated consisting of the details of the protocol of each test series, the incidence of Doppler detected venous gas emboli (VGE), the incidence of symptoms of DCS, and the incidence of Type II DCS. In the course of the conduct of these trials, ancillary measurements were made in some cases to determine if test subjects had a PFO.

Several investigators have reported on the incidence of PFO in divers and aviators who experienced DCS and on the effect of PFO on the risk of DCS during an operational exposure (*13-16*). Conclusions were not consistent. The effect of a PFO on the risk of DCS and

particularly Type II DCS on astronauts conducting EVA is a concern for those responsible for the safety and well being of the crew. This concern is amplified by the large number of EVAs that will be conducted in the next few years in the construction of the International Space Station. The number of exposures and measurements of PFO in the JSC database are too small to reach any conclusions. However, the recent publication of Bove (*17*) using meta-analysis to make an assessment of the effect of PFO on the risk of DCS in operational diving, suggests that publication of all pertinent data in this area is worthwhile even though the number of cases arising in a particular experimental series may be small. The purpose of this report is to present the data on DCS, Type II DCS and PFO from altitude chamber trials simulating the DCS stress of EVA in a form that may contribute to decisions as to whether or not screening for PFO in the astronaut population is warranted.

Materials and Methods

Forty-five subjects were tested for the presence of PFO. Three of these subjects were tested because they had experienced a prior episode of Type II DCS during experiments of EVA-like decompression protocols. The remaining 42 subjects were tested for PFO as part of a study on the prevalence of PFO in experimental subjects that volunteered for participation in DCS studies. The presence or absence of a PFO detected in these tests had no effect on the eligibility of a subject to participate in decompression studies at JSC, and some subjects did choose to participate in such studies. The protocols for each of these DCS studies and for the study on the presence of PFOs were reviewed and approved by the JSC human use committee.

Echocardiographic Studies

The echocardiographic studies were conducted in the JSC Cardiovascular laboratory utilizing an Advanced Technology Laboratories Ultramark 8 echocardiograph for the first 18 determinations and an Ultramark 9 for the last 27 determinations. A complete 2D, M-Mode, Doppler and color Doppler echocardiogram was performed consistent with standards established by the American Society of Echocardiography. With contrast injection the subcostal four-chamber view was the preferred view to display the presence or absence of a PFO. When the subcostal view was sub-optimal, the apical four-chamber view was used either instead of or in addition to the subcostal view. All four cardiac chambers and valves were carefully examined. Special attention was paid to the interatrial septum. A determination of the presence or absence of PFO was made with Doppler color flow echocardiography (CFE) alone and with transthoracic echocardiography with contrast (TTEC) with and without a Valsalva maneuver.

Contrast echocardiography was performed by injecting a 5 cc bolus of agitated saline solution from a syringe through a two-way stopcock into a 20-gauge catheter inserted into the brachial vein. The injections were repeated until good contrast presence had been obtained in the atrium throughout a heart cycle. Up to eight injections were done to assure a good determination. The contrast echocardiography was then repeated in the presence of a Valsalva maneuver. Two procedures were used to accomplish the Valsalva maneuver:

1) subjects forcefully expired against a closed tube with a pressure gauge and maintained a pressure of 20 cm H_2O for at least 5 seconds; the resistance was then suddenly removed by turning a respiratory valve,

2) subjects forcefully expired against a closed glottis for at least 5 seconds and then expired freely upon command.

The first procedure was used for the first 18 trials. The last 27 trials used the second procedure. The saline injection was timed so that the contrast medium was in the right atrium and ventricle at the time of the release of the Valsalva. Again up to 8 injections were done to assure good timing as measured by the presence of contrast medium in the right chambers of the heart at the moment of and just after the release of the Valsalva and the presence of a good opaque contrast medium in the right chambers of the heart throughout at least 1 cardiac cycle. A positive determination of PFO was made when obvious microbubbles were observed in the left chambers immediately after the contrast medium had filled the right chambers.

Chamber Trials

The measurements of the presence or absence of a PFO were made in association with altitude chamber exposures that were done to assess the risk of candidate DCS protection protocols for space flight or to assess the risk of operations involving change in pressure in support of space flight. PFO measurements were made on some of the subjects participating in 6 separate studies, which involved 11 variations in procedure. The details of the test procedures for each of the studies are given elsewhere (*5-9*). A brief description of each of the studies is given here.

Bends 7 was a crossover study to assess the effect of a period of strenuous, protracted exercise on the risk of DCS. Each subject in the study was exposed to a trial at an average EVA work rate and a second trial that included a 1-hour period working at the highest work rate that the pressure suit could support by specification.

Bends 8 was a conducted to assess the effect of physical training on the risk of DCS. Trials were done with matched groups with and without physical training at the anaerobic threshold level for 3 days prior to the simulated EVA decompression.

Bends 9 was a conducted to assess the effect of bed rest as a simulation of prolonged weightlessness on the risk of DCS. Each subject was exposed to a trial preceded by 3 days of strict bed rest with bed rest continuing during the exposure and a second trial without bed rest. In a second part of Bends 9 an ambulatory chamber run was compared with runs in which the adynamia of microgravity was simulated by chair rest during denitrogenation and during the decompression and the same chair rest combined with exercise during the denitrogenation.

Bends 10 was an evaluation of a protocol to assure safe flying after diving. It included a six-hour dive simulated in a hyperbaric chamber followed by an altitude chamber exposure the next day.

Bends 11 evaluated the effectiveness of a reduced PB time in conjunction with chair rest and exercise during PB.

Measures of DCS

In each of these studies certain procedures and measures were common. In each altitude exposure an exercise regime was conducted that involved rotating through 3 exercise stations and 1 Doppler measurement station with 4 minutes being spent at each station for a full rotation and 1 Doppler sensing each 16 minutes. At the Doppler station a technician placed a transthoracic bubble detector in a position to detect flow in the pulmonary artery and listened for VGE while the subject made specific limb movements in all 4 quadrants. VGE were graded from Grade zero to Grade IV in accordance with the grading system introduced by Spencer (*18*). The subject was encouraged to report all symptoms and was queried at the end of each hour with a formal question that was to elicit any symptom of pain or discomfort in muscles, joints, or anywhere else. Simple limb pain was graded on a scale that included:

0 = no symptom

1 = Discomfort or joint awareness short of pain

2 = Pain that did not interfere with performance

3 = Pain that began to interfere with performance

In studies seven through 10 the trial was terminated at first incidence of Grade 3 limb symptoms or the first indication of any systemic symptom. In Study 11 the trial was terminated at first incidence of Grade 2 limb symptoms or the first indication of any systemic symptom.

Results

PFO determinations were made on 45 individuals. Three of these were made retrospectively on subjects who had experienced Type II DCS. Of these 3 subjects, 2 were positive for PFO at rest with TTEC. A group of 42 subjects were tested in a prospective trial. Of these subjects 1 individual (2%) was positive with CFE. Eleven subjects (26%) were positive with TTEC with the Valsalva maneuver. Nine of the individuals (21%) were positive with TTEC at rest. All individuals positive at rest were positive with Valsalva.

In 549 altitude decompression trials conducted between 1982 and 1998, there have been 5 instances of what we have classified as Type II symptoms of DCS. Throughout this time period cases of skin marbling or mottling received the same clinical treatment as Type II DCS, and more recently these cases have been categorized as Type II DCS incidents. One of the 5 instances was simple skin purities and rash that was followed by skin mottling in the same area (ID# 149-01). This individual was not tested for PFO. Of the 5 subjects with serious symptoms, 3 were tested for a PFO. The results are presented in Table 1.

The 3 subjects discussed above were tested for a PFO after they had experienced Type II symptoms. These subjects all experienced bubbles and limb pain before the onset of their Type II symptoms. There is additional data on 32 of the 42 subjects that were tested for PFO prospectively who participated in decompression trials. In these instances the results of the decompression tests did not influence whether or not a PFO test was performed. The incidence of VGE and symptoms in this population is shown in Table 2. Table 2 includes data on 7 different decompression protocols. Each differed from the others in the level of some controlled variable and in the risk of the protocol. Since some of these trials were crossover trials, the 50 trials were done on 32 subjects.

Table 1
Characteristics of the Five Cases of CNS or Cardiopulmonary Symptoms in the 549 Trials

ID#	R Value	Maximum 0_2PB	VGE Grade	PFO Test	Adynamia	Rx	DCS(%)*
18-02	1.75	yes	4	not done	no	0_2	3/11 (27)
123-01	1.78	no	4	+ at rest	no	0_2	6/22 (27)
121-01	1.78	no	4	negative	no	TT VI	3/11 (27)
149-01	1.78	no	4	not done	no	TT V	17/81 (22)
184-01	1.78	no	4**	+ at rest	yes	TT V	2/22 (9)

*Group incidence for the experimental series in which this case occurred.
**Grade 4 VGE assigned after the test was reviewed with Grade 0 recorded during the test.

Table 2
VGE and Limb DCS Symptoms versus PFO

	All Subjects			No PFO			PFO		
Series	n	VGE (%)	DCS (%)	n	VGE (%)	DCS (%)	n	VGE (%)	DCS (%)
9a	24	12 (50)	1 (4)	10	6 (60)	0 (0)	3	2 (67)	1 (33)
9b	23	6(26)	2(11)	9	1(11)	0(0)	2	0(0)	0(0)
9c	11	5 (45)	3 (27)	5	3 (60)	2 (40)	1	1 (100)	1(100)
9d	7	2 (28)	0 (0)	4	0 (0)	0 (0)	1	0 (0)	0 (0)

9e	7	2 (28)	0 (0)	3	1 (33)	0 (0)	1	0 (0)	0 (0)
10	19	6 (31)	0 (0)	6	3 (50)	0 (0)	0	0 (0)	0 (0)
11	28	7 (25)	3 (11)	4	2 (50)	0 (0)	0	0 (0)	0 (0)
Total	119	34 (34)	9 (8)	42	17 (40)	2 (5)	8	3 (37)	2 (25)

DISCUSSION

The incidence of PFO in the tested population of those with a Type II incident of DCS was 3 times as high as the incidence of PFO in the base population; however, the numbers are too small to have any statistical significance. The difference may have occurred by chance. A contingency test using Fisher's exact probability results in a $p = 0.22$. The individual who had a negative test for PFO experienced a rather severe Type II symptom that increased in severity at ground level and was slow to resolve during a U.S. Navy TT VI treatment. These findings are consistent with reports that a PFO increases the risk of Type II DCS but is not a precondition to such symptoms. The prevalence of PFO observed in our subjects is somewhat higher than that of most reports. However, the range of published data is large, and some of the more recent reports using transesophageal echocardiography with contrast show incident rates higher than those reported in autopsy studies (*15*,*25*).

Table 3
Incidence of PFO Reported in Various Control Studies

Investigator	n	Technique	Rest %	Valsalva %
Hagen (*19*)	965	Autopsy	24	
Guggiari (*20*)	218	TTEC*	6	10
Webster (*21*)	40	TTEC*	7.5	15
Lechat (*22*)	100	TTEC	5	10
Lynch (*23*)	76	TTEC	5	18
Wilmhurst (*13*)	63	TTEC	11	24
Cross (*24*)	78	TTEC	Not reported	31
Kerut (*15*)	30	TTEC	Not reported	17
		TTEC	Not reported	17
		TCDC*	Not reported	47

		TEEC	Not reported	23
Job (*25*)	63	TEEC	Not reported	43
Present Study	43	TTEC	21	26

*TEEC = Transesophageal echocardiograph with contrast media
*TTEC = Transthoracic echocardiograph with contrast media
*TCDC = Transcranial Doppler with contrast media

The relation of VGE or Type I DCS symptoms to the presence or absence of a PFO is presented in Table 2. The incidence of Doppler detected VGE during decompression does not appear to have been influenced by the presence or absence of a PFO, which is not surprising. The incidence of simple limb bends is higher in the population that tested positive for PFO, and this is consistent with the findings of Bove (*17*), but this finding is based on only 2 incidents both with the same subject. Since there were 7 different decompression protocols with different controlled variables and some subjects were involved in more than 1 trial, to assess this data statistically would require some approach to normalization of the trials and some assessment of the repeatability of the results of an individual to decompression. The limited data does not justify pursuit of these approaches.

Summary

This study is far too limited in scope to answer the question "Does a PFO in an EVA crewperson increase the risk of DCS in that individual?" This data is consistent with the position that a PFO may increase the risk of DCS. There is considerable variation in the incidence of PFOs in studies reported in the literature. Any plan to screen for PFOs in the population would have to be very specific in its intent and in recommended specific procedures.

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13. ABSTRACT *(Maximum 200 words)*

One hundred and three cases of hypobaric decompression sickness (DCS) are documented, with 6 classified as Type II DCS. The presence and grade of venous gas emboli (VGE) are part of the case descriptions. Cases were diagnosed from 731 exposures in 5 different altitude chambers from 4 different laboratories between the years 1982 and 1999. Research was funded by NASA to develop operational prebreathe (PB) procedures that would permit safe extravehicular activity from the Space Shuttle and International Space Station using an extravehicular mobility unit (spacesuit) operated at 4.3 psia. Both vehicles operate at 14.7 psia with an "air" atmosphere, so a PB procedure is required to reduce nitrogen partial pressure in the tissues to an acceptable level prior to depressurization to 4.3 psia. Thirty-two additional descriptions of symptoms that were not diagnosed as DCS together with VGE information are also included. The information for each case resides in logbooks from 32 different tests. Additional information is stored in the NASA Decompression Sickness Database and the Prebreathe Reduction Protocol Database, both maintained by the Environmental Physiology Laboratory at the Johnson Space Center. Both sources were reviewed to provide the narratives that follow.

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