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PROCEDURES FOR DOPPLER ULTRASONIC MONITORING OF DIVERS FOR INTRAVASCULAR BUBBLES

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PROCEDURES FOR DOPPLER ULTRASONIC MONITORING OF DIVERS FOR INTRAVASCULAR BUBBLES

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Abstract

Doppler ultrasonic detection of intravascular bubbles is a routine procedure for several laboratories engaged in decompression research. This technical communication recommends standard procedures to be followed in using the Doppler technique. The choice of monitoring sites is discussed. The two cases for observation, rest and movement, are described, and recommendations for scheduling the observations are given. Hints for making good, well-documented tape recordings of the Doppler signal are included. The *K-M Code* for describing the results is explained, and recommendations for the information that should be stored in records are given. Some difficulties in interpreting signals are discussed.

1. Introduction

Aural detection of bubbles in Doppler ultrasonic signals is now used by several laboratories in testing experimental decompression profiles. While the technique is simple and inexpensive, its application requires skill and concentration. The purpose of this technical communication is to describe the procedures used for Doppler ultrasonic bubble detection at DCIEM. Similar procedures are used at the Centre d'Etudes et de Recherches Techniques Sous-Marines (CERTSM) in France, and at the U.S. Navy Experimental Diving Unit, the U.S. Naval Submarine Medical Research Laboratory, and the U.S. Naval Medical Research Institute. So that the results of any group can be readily understood by the other workers, it is desirable that standard procedures be followed.

These instructions are based on an earlier set prepared by K.E. Kisman, formerly of DCIEM, and G. Masurel, of CERTSM. Further experience with the Doppler technique has led to refinements of the method; these are included in the present instructions. The Kisman-Masurel (K-M) Code [1] [2] is described. This code is used by the listener to classify the Doppler signals according to the bubbles identified. This classification is comparable to one developed by Spencer [3], but considers more factors, and permits a more detailed description of the Doppler signals. The K-M and Spencer Codes are similar enough, however, that results described using either method can be compared to some extent.

In this communication the choice of body sites for monitoring is discussed. Two cases for observation, *rest* and *movement*, are then described, and a schedule for monitoring is recommended. Hints for making good, well-documented recordings are given. The rules for classifying signals with the K-M Code are described. Recommendations for written records are made. Finally, some occasional problems are discussed.

2. Sites

It has become routine practice to monitor three body sites for bubbles – the precordium and each of the subclavian veins.

2.1. Precordium

The right heart should be monitored, because any bubble that enters the venous system, and persists, should pass through the right heart before being eliminated at the lungs. (Bubbles are rarely found on the arterial side. It is thought that they reach the arterial side only when the venous bubbles are so numerous that the filtering capacity of the lungs is overwhelmed [4] [5].) By monitoring the heart, therefore, it is possible, in principle, to estimate the total number of bubbles entering the blood at a given time. In practice, not all bubbles can be detected, because the amplitude of the signal from smaller bubbles may be less than that of the background cardiac and blood flow sounds. Therefore, only a rough estimate of the number of bubbles is possible.

Correct placement of the ultrasound transducer over the heart is critical for bubble detection (Figure 1). The following steps are recommended: A liberal quantity of gel should be applied to the transducer probe. By moving the probe over the precordium, it is possible to distinguish characteristic heart sounds associated with motion of the heart walls and valves, and with blood flow. The signal from the blood flow (a liquid, swishing sound) in the right side of the heart should be maximized. The repetitive sound of the atrioventricular valve may help in locating the optimum placement, but since the valve sound tends to mask the signals from bubbles, if they are present, the valve sound should not be allowed to dominate. For some especially deep-chested divers it may be difficult to obtain a good precordial signal. More searching may be required. If the diver bends forward slightly at the waist, to bring the heart nearer to the chest wall, the signal strength may be increased. For some divers the pulmonary artery, leading from the heart to the lungs, may afford a good monitoring location. When placing the transducer probe, *some exploration should always be done,* before settling on the best signal for recording. Experience has shown that *this can make the difference between detecting bubbles and missing them.*

2.2. Subclavian veins

Because it is sometimes difficult to obtain a good precordial signal, and because the precordial signal has a large background component, it is possible to miss bubbles at that site. It is therefore recommended that other sites be checked. The subclavian veins are easy to monitor (Figure 2), and the bubbles are readily distinguished when they are present. For these reasons, at DCIEM and CERTSM, it has become routine to search for bubbles in the subclavian veins as well as in the heart. Experience has shown that it is frequently possible to detect bubbles in the veins, when it is impossible to detect them in the heart, even though the bubbles should enter the heart only a short time after passing through the veins. It is not enough to monitor only the subclavian veins, however, because bubbles arriving from other parts of the body would then be missed.

The subclavian vein runs under the clavicle, or collarbone. It produces a characteristic Doppler signal sounding like a gentle, blowing wind. This sound becomes louder when the subject increases the flow of blood through the vein by clenching the fist on the side being monitored. The vein lies close to the subclavian artery, recognizable by its pulsing sound. The probe should be positioned to maximize the signal from the vein, and minimize that from the artery.

2.3. Other sites

If time permits, it may be profitable to monitor other sites as well. The femoral veins or the inferior *vena cava* can be checked for bubbles originating in the legs. The inferior *vena cava* is difficult to reach. The probe must be pushed deep into the abdomen, slightly to the left of centre as seen facing the subject (Figure 3). It is important not to confuse sounds from the intestines with bubble sounds. To check for bubbles originating in the head, the jugular vein could be monitored (Figure 4). When bubbles are extremely numerous in the heart, it may be worthwhile to check the carotid artery, to see if any are reaching the arterial side.

3. Cases

Monitoring should be done at each site for two cases – standing at rest (Figure 5), and after a well-defined movement. The purpose of this movement is to cause a momentary increase in the number of bubbles passing by the transducer. This helps the observer identify the bubbles. It is particularly useful when bubble counts are low, because the observer is then apt to miss the bubbles entirely.

For the precordial site this movement is a *deep knee-bend (Figure 6)*. The subject is asked to *flex*. After a short pause, the subject squats down and stands up in a continuous, smooth motion. During this time the subject must hold the transducer probe firmly at the site selected by the observer, so that the probe does not slip, or the signal will be lost.

For the subclavian sites, the movement is a momentary clenching of the fist on the side being monitored, followed by relaxation.

If the inferior *vena cava* or femoral veins are monitored, the subject may be asked to lift one leg and later the other. This may identify the source of the bubbles.

4. Timing

Doppler ultrasonic monitoring is not a continuous process, but a sampling process, because divers are checked for bubbles at certain intervals of time only. The appropriate intervals depend on the decompression. These intervals must be frequent enough so that bubbles are not missed should they occur.

Before each dive, it is advisable to obtain a reference recording at the precordial site for each subject. If, later, the observers are uncertain about the presence of bubbles, they can listen again to the reference signal to help resolve the question. Furthermore, making the reference recording helps the observers to become familiar with each subject's characteristic heart sounds.

For bounce dives, the subjects should be monitored at half-hour intervals for at least two hours from the start of the decompression, or until the bubbles have either disappeared, or diminished to low counts. If there are decompression stops longer than 15 minutes, monitoring should begin in the chamber during the stops. For saturation dives it is enough to monitor the divers several times a day, depending on the rate of the decompression. In any case, if monitoring is too infrequent, bubbles may be missed. This may result in an incorrect conclusion about the safety of the dive.

5. Recording Hints

For convenience, tape recording using the cassette format is recommended. Good recordings of the Doppler signals are essential for several reasons:

Signals that are difficult to assess can be played back.
Another person can verify the results, or make the assessment if this has not been done.
The signals may be used as input to a signal processor for automatic bubble counting.

Consistently good recordings can be obtained by following these recommendations:

1. A good cassette recorder with a standard noise reduction system should be used. (The most common noise reduction system is Dolby B, but recent machines may have Dolby C, and DBX as well. DBX permits higher dynamic range, but it is incompatible with both Dolby B and C, so it should be used only if it is certain that the tape will be played back on a machine with DBX. It is possible to play back tapes recorded with Dolby C on machines with only Dolby B, and both Dolby B and C tapes can be played back on machines without either noise reduction system. There is a loss of signal fidelity, however.) Machines with three magnetic heads (one each for erasing, recording, and playback) have the advantage that the signal can be monitored from the tape as it is being recorded, thus verifying the success of the recording. This allows immediate corrections to be made.

2. Quality cassettes should be used. For greater dynamic range, chromium dioxide (Type II) cassettes are recommended, but standard low-noise, ferric (Type I) cassettes are adequate. Sixty-minute cassettes are more robust than ninety-minute cassettes. The cassette case should be of the type fastened with screws so that it can be repaired if the tape becomes jammed or broken.

3. A separate cassette should be used for each diver in a given dive. This greatly facilitates following the evolution of bubbles in a diver over time by reducing the time spent searching during play-back. (The same cassette can be used for later dives in the series by the same diver, until the tape is full.)

4. The Doppler signals should be recorded on one track, and voice comments on the other track. This helps in eliminating unwanted voice signals if the tapes are played back to a signal processor. It also allows separate record levels to be set for each input, and minimizes the amount of adjustment needed during recording.

5. Complete voice comments shou'd be made. At the beginning of the tape (but not on the leader) the diver, the date, the profile, and the diver's role should be identified. Before each evaluation, the diver's name should again be recorded (to allow correct identification if the signal is recorded on the wrong tape). Also, the time from the start of decompression, and the pressure or depth should be recorded.

6. Along with the voice comments, a complete written record of the evaluations should be kept, using sheets such as those included in Appendix A.

7. While recording, the signal level indicators should be watched to ensure that the signal amplitude is high enough for a good recording, but not high enough to cause tape saturation. Occasionally, a section of tape should be played back, to verify that the signal is being recorded properly. On three-headed machines, this can be done while recording by setting the monitor switch to *tape*.

8. If possible, observers should work in teams of two – one to place the probe and maintain the signal, and the other to do the recording. Both observers should do the assessment, and seek a consensus.

9. The following timings should be used for recordings:

Precordial rest – 60 seconds
Precordial movement – 3 flexes, 30 seconds after each
Subclavian rest – 30 seconds
Subclavian movement – 3 flexes, 15 seconds after each

Although these times may sometimes seem long, they are necessary because bubbles are usually rare events. Longer observation times provide a more accurate description of the results. Keeping the sampling intervals and durations the same aids statistical comparisons, and is part of good experimental method.

6. Assessment

6.1. Parameters

Three parameters are used to describe the bubble signal. Each parameter is assigned a classification from 0 to 4. The first and third parameters, *frequency* and *amplitude,* are identical for the two cases – *rest* and *movement.* The second parameter differs. For the *rest* case, it is called *percentage,* while for the *movement* case, it is called *duration.* The combination of these three parameters yields a three-fold classification, the *K-M Code,* for each assessment. This three-fold classification is reduced to a single *Bubble Grade* by referring to Table 5 (p. 9).

6.2. Frequency – both cases

Th. first parameter, *frequency,* represents the number of bubbles per cardiac period. The rules for grading this parameter are listed in Table 1.

Table 1. Frequency parameter

Code	Frequency
0	0
1	1 - 2
2	several 3 - 8
3	rolling drumbeat 9 - 40
4	continuous sound

For code 4, the bubbles are so numerous that they cannot be individually distinguished.

6.3. Percentage – rest case

The *percentage* parameter represents the percentage of cardiac periods having a specified bubble frequency. The rules for grading this parameter are listed in Table 2.

Table 2. Percentage parameter

Code	Percentage
0	0
1	1 - 10
2	10 - 50
3	50 - 99
4	100

For example, if out of 100 heart beats, 1-2 bubbles (*frequency* code 1) were detected in 20 of them, then the *percentage* code would be 2. If 40 heart beats had 1-2 bubbles, and 20 had 3-8 bubbles, then *percentage* code 3 could apply for *frequency* code 1, because over 50 per cent of the heart beats had at least 1-2 bubbles. However, *percentage* code 2 would apply for *frequency* code 2, because between 10 and 50 per cent of the heart beats had 3-8 bubbles. It is often possible to describe the same signal in more than one way. This will be discussed further in the last section.

6.4. Duration - movement case

The *movement* case is a transient event, while the *rest* case is at least a quasi-steady-state event. Because of this difference, the second parameter for the movement case is *duration* instead of *percentage*. The *duration* is counted as the number of successive cardiac periods following the movement, having at least a specified bubble *frequency* – the first parameter. The first such period must occur within 10 heart beats following the movement. The rules for grading the *duration* parameter are listed in Table 3.

Table 3. Duration parameter

Code	Duration (heart beats)
0	0
1	1 - 2
2	3 - 5
3	6 - 10
4	> 10

For example, if 6-10 bubbles were counted in each of the first four heart beats following the movement, *duration* parameter 2 would apply for *frequency* parameter 3. If the number of bubbles counted per heart beat then fell to 3-5 for the next four heart beats, then *duration* parameter 3 could apply to *frequency* parameter 2, because there would have been at least 3 bubbles per cardiac cycle for 8 heart beats following the *flex*.

6.5. Amplitude - both cases

The amplitude of the bubble signal, A_b , is compared to the amplitude of the normal cardiac sounds, A_c, using the rules listed in Table 4.

Table 4. Amplitude parameter

Grade	Amplitude
0	no bubbles discernible
1	barely perceptible, $A_b << A_c$
2	moderate amplitude, $A_b < A_c$
3	loud, $A_b \simeq A_c$
4	maximal, $A_b > A_c$

Usually, these three parameters are evaluated in the order presented here. Initially it may be necessary to replay the recording of the signal several times to classify each parameter, but with practice, the observer should be able to do the classification while recording the signal.

The resulting K-M Code is written in the form *fpa* for the rest case and *fda* for the movement case, where the three letters represent the grades assigned for the frequency, percentage or duration, and amplitude parameters, e.g. 112. Table 5. (p. 9) can be used to obtain the global bubble grade corresponding to the K-M Code (e.g. 112 → I). This is convenient for describing the results, but the original K-M Code should always be recorded, since it contains more information.

7. Other Data

Besides recording the audio signals and the bubble codes, and completely identifying these records, there are many other items of information that are useful in analysing the dives. Examples are information about the dive itself; about the diver, such as height, weight, and age; and about any occurrence of decompression sickness (DCS). At DCIEM, the divers are asked to fill out a questionnaire after each dive, describing their subjective feelings and any events that might have had a bearing on the outcome of the dive (Appendix B). At the time of the first medical examination, before a series of dives, the information in Appendix C is requested. This questionnaire includes items about the lifestyle of the subject, such as smoking and drinking habits, and whether the subject exercises regularly. This information may help to determine wha, factors are related to the incidence of DCS, or the tendency to produce bubbles.

Most of the information is stored in one of two data bases. Basic dive data are stored in *CANDID* [6] [7], and Doppler results are stored in *BUBBLES*. Appendix D lists the questions used to prompt the person who enters the Doppler data into *BUBBLES*. Not all of this information would necessarily be available, but an attempt has been made to foresee and allocate space for most data of potential use. This data base uses the INGRES Data Base Management System*, running under UNIX†. It is flexible enough to permit addition of other items of information at a later date. It is recommended that Appendix D be used only as a guide for deciding what data to collect.

Table 5. K-M Code → Bubble Grade

fpa	g	fpa	g	fpa	g	fpa	g
111	I–	211	I–	311	I	411	II–
112	I	212	I	312	II–	412	II
113	I	213	I+	313	II	413	II+
114	I+	214	II–	314	II	414	III–
121	I+	221	II–	321	II	421	III–
122	II	222	II	322	II+	422	III
123	II	223	II+	323	III–	423	III
124	II	224	II+	324	III	424	III+
131	II	231	II	331	III–	431	III
132	II	232	III–	332	III	432	III+
133	III–	233	III	333	III	433	IV–
134	III–	234	III	334	III+	434	IV
141	II	241	III–	341	III	441	III+
142	III–	242	III	342	III+	442	IV
143	III	243	III	343	III+	443	IV
144	III	244	III+	344	IV–	444	IV

fp(d)a – K-M Code
f – frequency parameter
p(d) – percentage (or duration) parameter
a – amplitude parameter
g – Bubble Grade

* Electronics Research Laboratory, College of Engineering, University of California, Berkeley

† UNIX is a trademark of Bell Telephone Laboratories

8. Difficulties

The most difficult aspect of Doppler ultrasonic bubble detection is recognition of the bubbles in the heart, because the bubble signals are masked by the normal cardiac sounds. Unfortunately, this can only be mastered with practice. It is recommended that those learning the technique be instructed by someone experienced in the technique.

There are, however, some principles that can be applied. The bubble sounds are transient in nature, and they often appear irregularly during the cardiac cycle. When they can be distinguished individually, they sound like chirps, whistles, and pops. Valve sounds, on the other hand, are heard about the same time during successive heart beats, and make a whipping sound. Unfortunately, because of the pumping action of the heart, the passage of bubbles may be well-correlated with the heart beat, and sometimes it may be difficult to distinguish the bubbles from valve flutter. In these situations, it may be useful to try the pulmonary artery, and to listen again to the pre-dive reference recording. The *flex* often helps to verify the presence of bubbles. Detection of bubbles in the subclavian veins should alert the observer to the likelihood that they are also present in the heart.

The Doppler signal can sometimes be interrupted, either by movement of the probe, or by movement of the underlying anatomical structures, during respiration or during a *flex*. When this happens, it is best to interpolate the bubble counts for the duration of the interruption.

The *duration* parameter for the *movement* case was specified in cardiac cycles. Since for the subclavian site, it may be difficult to count heart cycles, the duration should be counted in seconds instead.

It is frequently possible to assign more than one classification during a single evaluation. To decide which classification to use, the global bubble grade should be obtained for each K-M Code, and the greatest should be chosen. For example, the codes 232 and 322 might both apply for an evaluation. From Table 5, the Grade for 232 is III-, while that for 322 is II+, so 232 is chosen. For the movement case, each flex should be classified, and the most representative code chosen. For example, if the Codes 222, 222, and 232 were assigned to the three flexes, 222 would be chosen. If codes 222, 232, and 332 were assigned, the middle value, 232, would be chosen. The exception to this rule occurs when two flexes both yield 0, while the other produces bubbles. In that case, the higher classification should be selected, because it is most important to distinguish between instances with bubbles and those without. When choosing between K-M Codes, the Bubble Grade Table, Table 5, should always be consulted, since the ordering of the K-M Codes is not always obvious.

The rules for evaluating the subclavian signals are the same as for evaluating the precordial signals. The duration of the increase in flow after clenching the fist is briefer, however – rarely more than 4 seconds. As a result, lower bubble grades are sometimes obtained for the movement case than for the rest case, even though there was a brief increase in the number of bubbles. This is perhaps anomalous. Therefore, the rules for grading the *duration* parameter for the subclavian *movement* case may be changed in the future.

Procedures for interpreting the results of Doppler ultrasonic bubble detection will be discussed in a later publication. It should be observed, however, that bubble grades are categories, not numbers, and should be treated as categorical data.

Acknowledgements

These procedures are due in large part to the work of Monsieur Gérard Masurel, of CERTSM, and Dr. Kenneth Kisman, formerly of DCIEM. We thank Mr. David Eastman, Mr. Stanley Macdonald, PO1 George Carrod, and PO2 Bruce Law, for testing and refining the procedures, for their comments on this communication, and for their many hours of effort collecting data.

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Fig. 1 Placement of the Doppler ultrasound transducer in the precordial region.

Fig. 2 Placement of the Doppler ultrasound transducer over the left subclavian vein.

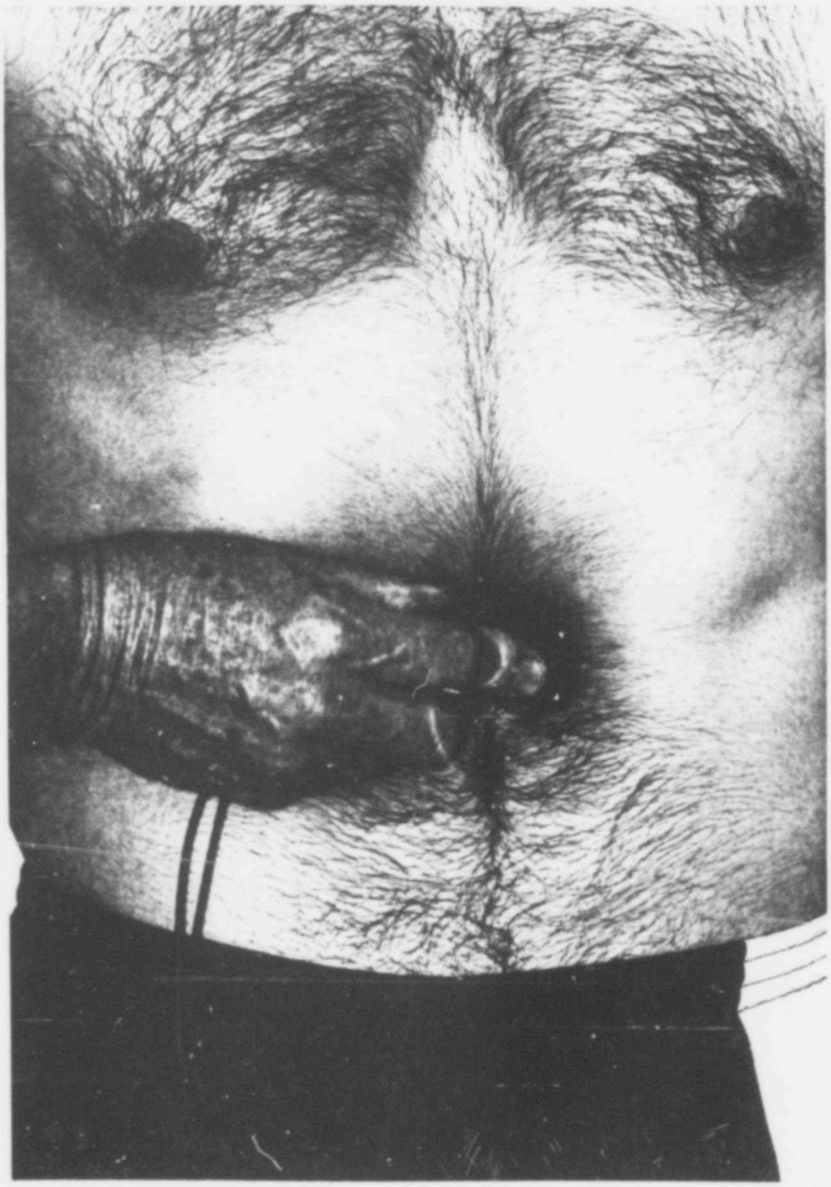

Fig. 3 Placement of the Doppler ultrasound transducer for the inferior *vena cava*.

Fig. 4 Placement of the Doppler ultrasound transducer over the jugular vein.

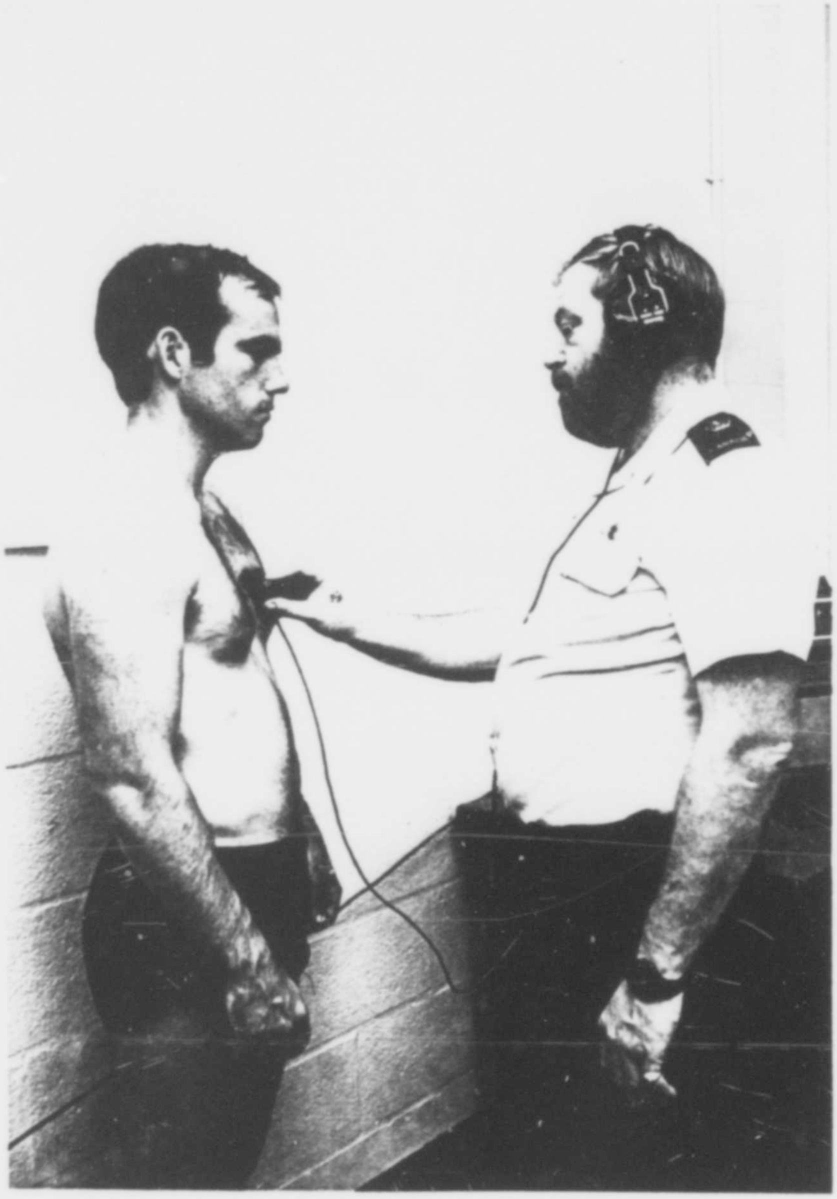

Fig. 5   A subject standing at rest.

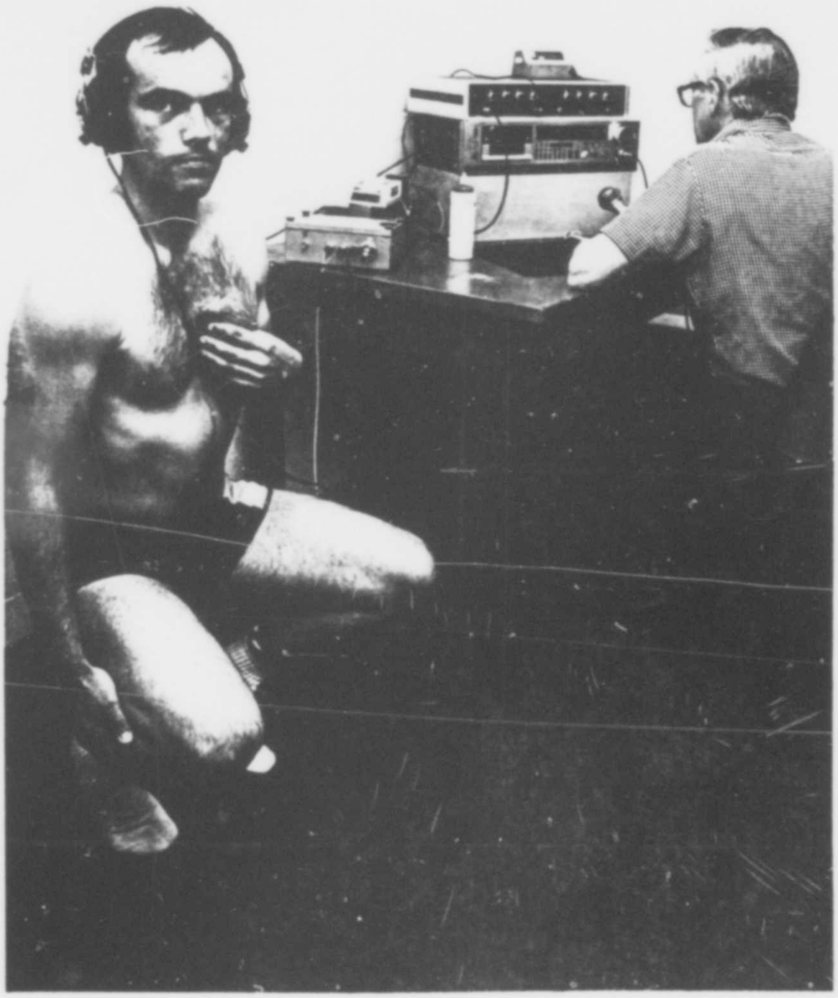

Fig. 6 A subject doing a *deep knee-bend* for the movement case.

APPENDIX A

DCIEM DOPPLER DATA

Diver.. Date.................................... Profile..............................

Diver's Role............................. Start Time.......................... Wet Dry

Sex............... Dive#.................................. Water Temp.....................

Monitor...................... .... Series Name........................ Work Type...... ....

Remarks:

Eval.		Heart		Shoulders				Other
	Time / Depth	Rest	Move	L/Rest	L/Move	R/Rest	R/Move	
		Grade						

APPENDIX B

DIVE QUESTIONNAIRE

NAME: ____

Profile Dived: ______________________________

Date Dived: ______________________________

1. In the 24 hours prior to the dive did you participate in physical exercise? Yes No

2. If so, what did you do?

3. Is this a regular activity? Yes No

4. Did you injure or stress any part of your body? Yes No

5. If so, please describe the injury or stress.

6. What medication, if any, did you take during the 24 hours prior to diving?

7. What was your alcohol intake during the 24 hours prior to diving?

8. If you are a smoker, how many cigarettes/cigars/pipefulls did you smoke in the 24 hours prior to diving?

9. If you dove previously in this series, did you have any unusual feeling of fatigue or mood in the 24 hours following your last dive?

10. If so, please describe these feelings, and give the date of the dive.

APPENDIX C

DOPPLER SUBJECT INFORMATION*

Date: __________

1. Name in full, underline the given name normally used:

____

2. Date of Birth: ______________________

3. Height: ____________

	Beginning of Series	End of Series
4. Weight:	____________	____________
5. Skinfold (in mm):		
biceps	____________	____________
triceps	____________	____________
subscapula	____________	____________
suprailiac	____________	____________

6. Smoker? Yes____ No ____ Typical daily amount? ____________

7. Alcohol consumption? Yes ____ No ____ Typical weekly amount? ________

8. Medication used regularly? Yes ___ No ___ Type? ____________

9. Regualr exercise? Yes ____ No ___ Frequency? ____________

10. Past injuries, especially trauma to limbs?

____

____

____

* To be completed once for each dive series, voluntary.

APPENDIX D

List of questions for input to the Doppler ultrasonic data base, BUBBLES

The terminal input programme, enter.c, prompts for the following information. Use these sheets to prepare the information in advance. There are separate sheets for:

1. Dive Series Information
2. Dive Information
3. Diver Information
4. Man-Dive Information
5. Decompression Sickness Information
6. Signal Processor Evaluations

For Doppler codes obtained by ear, use the original scoring sheets directly.

APPENDIX D continued

1. Dive series information

1. Series identification number?
2. Series name? (20 characters max)
3. Type of dive? (1-3 characters) If the dives are repetitive dives, add the letter r to the following designations. If different dives in the series use different gases, use only the first letter.

bounce dives	air	ba
	heliox	bh
	nitrox	bn
	oxygen	bo
saturation dives	air	sa
	heliox	sh
	nitrox	sh
	trimix	st
excursions	air	ea
	heliox	eh
	nitrox	en
	trimix	et

4. Starting date? (YYMMDD)
5. Ending date?
6. Location? (10 characters)
7. Number of dives?
8. Number of man-dives?
9. Remarks? (80 characters max)

APPENDIX D continued

2. Dive information

1. Dive series identification number? (as above)
2. Dive identification? (up to 10 alphanumeric characters as in CANDID)

3. Max depth? (msw)
4. Bottom time? [DD:HH:]mm[.ss]
5. Total dive duration? [DD:HH:]mm[.ss]
6. Dive name? (20 characters max)
7. Dive type? (as for series; for repetitive dives add the suffix r, and the number of the dive, e.g. bar1 (bounce air repetitive, first dive))
8. Source of the dive profile? (up to 10 characters)
9. Profile number? (up to 10 alphanumeric characters)
10. Remarks? (up to 80 alphanumeric characters)

11. Starting date? (YYMMDD)
12. Start time? (hh:mm 24 hour clock)
13. Environment? (eg. chamber wet, (20 characters max))

14. Any water temperature readings (degrees C) and the time of reading.

APPENDIX D continued

3. Diver information

1. Diver identification number?
2. Diver's name? e.g. Surname IN (20 characters max)
3. Sex? (m or f)
4. Birth date? (YYMMDD)
5. Height (cm) ?
6. Skinfolds data - date of measurement?
7. biceps (mm)?
8. triceps (mm)?
9. subscapula (mm)?
10. suprailiac (mm) ?
11. Date of weighing?
12. Weight? (kg)
13. $\dot{V}O_{2max}$? (ml/kg/min)

APPENDIX D continued

4. Man-dive information

1. Series identification number? (as before)
2. Dive id? (as before)
3. Diver number? (as before)
4. Man-dive identification number?
5. Name of observer? (20 characters max)
6. Diver's role? (2 characters max)

leader	l
tender	t
standby	s
wet-working	ww
dry-working	dw
wet-resting	wr
dry-resting	dr

7. Remarks (up to 80 characters)

8. Core temperature measurements (degrees C) and the time of each measurement from the start of the dive. Time first, then temp.

9. Work type? (10 characters max e.g. bike, swim, weights, etc.)

10. The diver's maximum work rate in Watts?

11. Various work rates and the time from start of dive when each rate was reached. Time first, rate second.

APPENDIX D continued

5. Decompression sickness data

1. Decompression sickness symptoms: (15 characters max)
   - I pain - location (e.g. I - elbow)
   - II Cerebral (only II required)
   - III Spinal
   - IV Vestibular
   - V Chokes
2. Time of onset of dcs? (re. start of decompression)
3. Pressure at onset of dcs? (msw)
4. Treatment? (20 chars max) (e.g. Table 5)
5. Time symptoms relieved? (re. start of decompression)
6. Pressure when symptoms relieved? (msw)
7. Medical officer? (20 characters max)
8. Remarks (up to 80 characters)

APPENDIX D continued

6. Doppler data

1. Number of times this subject was monitored for this dive?
2. Time of evalation?
3. Pressure (depth) of evaluation (MSW)?
4. Doppler score (K-M Code e.g. 112)?

The programme will prompt for all the data. Refer to the original score sheets.

APPENDIX D continued

7. Signal processor evaluations

For each evaluation with the signal processor, enter the following data:

1. time
2. depth (msw)
3. condition (e.g. precordial rest) (20 chars max)
4. total no. of bubbles detected.
5. peak no. of bubbles detected per second
6. mean no. of bubbles detected per second
7. standard deviation

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