Correlation between $^{99}\text{Tc}^{\text{m}}$ -HMPAO-SPECT brain image and a history of decompression illness or extent of diving experience in commercial divers

T G Shields, P M Duff, S A Evans, H G Gemmell, P F Sharp, F W Smith, R T Staff, S E Wilcock

Abstract

Objectives—To explore the use of $^{99}\text{Tc}^{\text{m}}$ -hexamethyl propylene amine oxime single photon computed tomography (HMPAO-SPECT) of the brain as a means of detecting nervous tissue damage in divers and to determine if there is any correlation between brain image and a diver's history of diving or decompression illness (DCI).

Methods—28 commercial divers with a history of DCI, 26 divers with no history of DCI, and 19 non-diving controls were examined with brain HMPAO-SPECT. Results were classified by observer assessment as normal (I) or as a pattern variants (II-V). The brain images of a subgroup of these divers ($n = 44$) and the controls ($n = 17$) were further analysed with a first order texture analysis technique based on a grey level histogram.

Results—15 of 54 commercial divers (28%) were visually assessed as having HMPAO-SPECT images outside normal limits compared with 15.8% in appropriately identified non-diver control subjects. 18% of divers with a history of DCI were classified as having a pattern different from the normal image compared with 38% with no history of DCI. No association was established between the presence of a pattern variant from the normal image and history of DCI, diving, or other previous possible neurological insult. On texture analysis of the brain images, divers had a significantly lower mean grey level (MGL) than non-divers. Divers with a history of DCI ($n = 22$) had a significantly lower MGL when compared with divers with no history of DCI ($n = 22$). Divers with > 14 years professional diving or > 100 decompression days a year had a significantly lower MGL value.

Conclusions—Observer assessment of HMPAO-SPECT brain images can lead to disparity in results. Texture analysis of the brain images supplies both an objective and consistent method of measurement. A significant correlation was found between a low measure of MGL and a history of DCI. There was also an indication that diving itself had an effect on texture measurement, implying that it had caused subclinical nervous tissue damage.

Key words: HMPAO-SPECT; decompression illness; diving

There is growing concern within the diving community that divers with a history of decompression illness (DCI) may have sustained nervous tissue damage which is subclinical. Such occult tissue damage could potentially give rise to clinically significant symptoms in later life. Various investigative techniques have been used in an attempt to provide objective evidence for this concern.

An example of so called functional brain imaging is $^{99}\text{Tc}^{\text{m}}$ -hexamethyl propylene amine oxime-single photon computed tomography (HMPAO-SPECT) which is used to show regional cerebral blood flow.¹ It has been extensively used to investigate patterns of functional brain deficit seen in different forms of dementia.^{2,3} Adkisson *et al* made initial use of HMPAO-SPECT brain images in their investigation of diving illness when they examined a series of 28 patients within a month of presentation of acute DCI and reported finding cerebral perfusion deficits in all the cases with neurological involvement.⁴ There also seemed to be a correlation between clinical presentation and site of deficit. However, there was criticism of this study because of population controls and scan interpretation. In a series of follow up studies on some of the original cases, it was reported that most of the observed perfusion deficits had persisted.^{5,6} Since publication of these initial reports, conflicting evidence has accumulated from various studies on the use of HMPAO-SPECT brain images in the study of DCI.⁷⁻¹¹

One possible explanation for conflicting reports with HMPAO-SPECT in the detection of perfusion deficits in divers is the variation that could arise as a result of inconsistency in observer assessment criteria of brain images, especially those of people with DCI, which has been described as a diffuse and multifocal disease.⁴ Analysis of HMPAO-SPECT brain images of divers by the measurement of texture based on a grey level histogram, provides an indication that divers with a history of DCI have a significantly lower textural measurement than diving control subjects, suggesting that DCI produces a detectable change in the HMPAO-SPECT brain image.¹³

The study described here formed part of a larger investigation into the potential long term neurological consequences of DCI in commercial offshore air divers.¹² This involved a series of neurological investigations includ-

Hyperbaric Research Unit, Robert Gordon University, School Hill, Aberdeen AB9 1FR
T G Shields
P M Duff
S A Evans

Department of Bio-Medical Physics and Bioengineering, University of Aberdeen, Foresterhill, Aberdeen
H G Gemmell
P F Sharp
F W Smith
R T Staff
S E Wilcock

Correspondence to:
Dr S E Wilcock, Hyperbaric Research Unit, Robert Gordon University, School Hill, Aberdeen AB9 1FR.

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ing neuropsychological and neurophysiological assessment and was also designed to explore the use of brain HMPAO-SPECT as a means of detecting nervous tissue damage in divers with and without a history of DCI. To investigate the possibility that texture analysis might provide a more objective and consistent measure of nervous tissue damage and to assess any association of this measure with a person's history of diving and DCI, the HMPAO-SPECT brain images from a group of offshore commercial divers were assessed both visually and by texture measurement for comparison.

Subjects and methods

STUDY POPULATION

About 30% of divers known to have carried out offshore commercial air dives in the United Kingdom continental shelf, were invited by letter to take part in the study.¹² Of those who volunteered to take part, 54 consented to have brain HMPAO-SPECT. Divers were questioned at interview on their history of DCI, diving, head injury, exposure to toxic fume, and use or misuse of drugs. Twenty eight divers (mean (SD) age 37.6 (4.8) years) had a history of DCI which was classified using the original decompression sickness (DCS) categories. Their histories of DCI varied from a single incident of DCS type 1 to multiple DCS type 1 and type 2 incidents. Twenty six divers (mean age 35.9 (4.1) years) had no history of any form of DCI including any untreated episodes or possible niggles. There was no significant difference between the two groups for age (independent *t* test, *df* = 52, *P* > 0.05).

Table 1 shows the diving history of the groups. In an attempt to measure the extent of decompression a diver had experienced, air, nitrox, sports, military, pure oxygen, and helium bounce dives were all afforded a single decompression day per dive. Each saturation (helium-oxygen) dive was afforded a notional score of five decompression days. The groups were found to be significantly different for total career dives and total decompression days in a career (two tailed independent *t* test, *df* = 52, *P* < 0.02), divers with a history of DCI having the greater diving experience. The groups were comparable for all other measures of diving history.

Few non-diving control subjects volunteered to have a scan. However, as well as nine control subjects originally investigated by this centre,² a further 10 subjects who contacted the unit through advertisement of the study or who were friends of the divers already taking part, were scanned giving a total of 19 non-diving controls (mean age 38.0 (7.7) years).

Texture measurement of the brain images from these subjects took place at least one year after the last original scan. Due to constant updating of the method of image storage, the brain images of only 44 of the divers could be reanalysed by measurement of texture; 22 divers (mean age 37.5 (5.2) years) had a history of DCI and 22 divers (mean age 35.7 (3.9) years) had no history of DCI. There was

no significant difference between these subgroups for age and all measures of diving history (table 1; two tailed independent *t* test, *df* = 42, *P* > 0.05). The HMPAO-SPECT brain scans from 17 non-diving control subjects were reanalysed by measurement of texture (mean age 43.9 (12.2) years).

METHODS

HMPAO-SPECT imaging

The protocol for ⁹⁹Tc^m-HMPAO-SPECT imaging was as follows: SPECT regional cerebral blood flow images were obtained after the intravenous injection of ⁹⁹Tc^m-HMPAO (750 mBq).¹³ Data acquisition was started 15 minutes after injection. Sixty four by 25 s frames were collected on a 64 × 64 matrix with a high resolution collimator fitted to an IGE ACT rotating gamma camera interfaced to a link analytical MAPS 5050 data processor. Reconstruction was by back projection of profiles filtered by a Hanning weighted ramp filter. Data were uniformly corrected for variations in centre of rotation.

Assessment of HMPAO-SPECT brain images was by two methods:

(1) Observer assessment

The scans were reported independently by nuclear medicine specialists who had no knowledge of the subjects' medical or diving histories. The results were classified into one of five pattern variants as follows: type a, scan appearance was judged to be within normal limits; type b, one or more large focal areas of absent uptake in the cerebral cortex similar to those seen in patients with a focal neurological deficit after cerebral infarction; type c, multiple small areas of reduced or absent uptake scattered globally throughout the cortex similar to those seen in patients with multi-infarct dementia; type d, a distinct pattern showing reduced or absent uptake in the watershed regions between territories of the middle and posterior cerebral artery and to a lesser extent between the middle and anterior artery, similar to those seen in patients with Alzheimer's disease; type e, a patchy but definite reduction in uptake in the temporal lobes and to a lesser extent in the adjacent inferior parietal and occipital lobes.

(2) Texture analysis

After acquisition and reconstruction as already described, a surface was produced with six adjacent reconstructed tomographic slices within the grey matter above the cerebellum. For each slice, the centre of the brain was found by a simple moment technique. A maximum pixel was located along a line from the centre of the brain ending at the edge of the brain in a particular direction. This was repeated for 64 equally spaced directions about the centre of each tomographic slice. The value of the texture surface corresponding to each particular line and tomographic slice was calculated by summing the two pixels either side of the maximum along the line. This technique of radial sampling is similar to the approach used by Ichise *et al*¹⁴ and has

Table 1 Professional diving history of subjects

Diving history Mean (SD) per person	Divers with a history of DCI	Divers with no history of DCI
<i>Subjects included in observer assessment</i>		
Number of divers	28	26
Number of years professional diving	14.5 (4.0)	14.4 (5.3)
*Total career dives	1031 (526)	728 (323)
Dives/year	71 (26)	57 (30)
*Decompression days in career	1146 (533)	826 (340)
Decompression days/year	78 (26)	64 (31)
Type of diving (n):		
Air/nitrox divers	8	4
Saturation divers (range of dives)	18 (1–102)	21 (1–90)
Saturation divers—course only	2	1
<i>Subjects whose brain images could be assessed by texture analysis†</i>		
Number of divers	22	22
Number of years professional diving	14.2 (3.8)	14.5 (5.5)
Total career dives	1026 (539)	752 (338)
Dives/year	70 (23)	58 (31)
Decompression days in career	1130 (543)	859 (355)
Decompression days/year	77 (22)	66 (32)
Type of diving (n):		
Air/nitrox divers	6	3
Saturation divers (range of dives)	14 (1–84)	18 (1–90)
Saturation divers—course only	2	1

*P < 0.02; two tailed *t* test.†No significant difference between groups P > 0.05 two tailed *t* test.

previously been described by Staff *et al.*¹⁵ Each pixel within this surface corresponds to a particular slice and direction within the brain. The production of the surface was automated to reduce observer bias. Quantitative measures of texture were calculated by rebinning the surface image into 16 equally spaced histogram bins between the maximum and minimum values of the surface image array and producing a probability histogram by dividing each bin by the total number of pixels. The first order measures of texture are a mathematical description of this histogram. The texture measurement chosen was the mean grey level (MGL)—that is, the mean of this histogram.¹⁶ The MGL is therefore a measure of global perfusion, being representative of the texture in the sampled area above the cerebellum in both hemispheres and in the frontal and occipital lobes. The MGL values ranged from 9.74 to 4.11, higher values being considered to be more normal.

INDICES OF A HISTORY OF DCI AND HEAD INJURY

History of DCI for the 28 subjects was divided into three generalised categories of severity by an experienced diving physician, based on the number, symptomatology, and original classification of incidents into DCS type 1 or type 2¹²: (a) subjects who had only had DCS type 1 incidents (n = 11); (b) subjects who had had a DCS type 2 of whom some had also had DCS type 1 incidents (n = 7); (c) subjects who had had multiple DCS type 2 incidents of

whom some still had residual (n = 10).

The most recent incident before the brain HMPAO-SPECT was classified in eight subjects as DCS type 2 and in 20 subjects as DCS type 1. The time interval between the last incident and the brain scan ranged from five months to 13 years six months (mean 6.75 (3.75) years).

An index of the severity of head injury and exposure to toxic fume was created on a scale from 0 (negligible/not significant) to 3 (severe/definitely significant) by two physicians independently who were blinded to each other's assessment and to other information on the subject. The values attributed by each physician correlated almost totally.

STATISTICAL ANALYSES

Data were analysed with the statistical package SPSS-X on a mainframe computer (Honeywell CP-6). Parametric tests—such as one or two tailed *t* tests were used as appropriate. A χ^2 test was used to examine differences in observer assessment. Non-parametric tests were used in other cases—for example, in examining possible correlation between observer assessment of the brain HMPAO-SPECT and history of DCI, the Spearman correlation coefficient was calculated. A probability of < 0.05 was taken as the criterion for there being a significant difference. Sometimes statistical analysis was not undertaken due to the small size of the groups, especially when criteria for matching subjects were applied.

When there was a significant age difference between groups, analysis was carried out with age matched pairs. Subjects were matched for age within two years and presence or absence of history of DCI when appropriate. To remove any influence of diving history on the findings when this particular factor was not being examined, subjects were also matched for various measures of diving history—for example, air or saturation diver, total number of dives, and where possible, number of dives for each type of diving and years of professional diving.

The possible contribution of other factors—such as head injury and misuse of drugs—was examined separately for each factor.

Results

HMPAO-SPECT BRAIN IMAGES AND DCI HISTORY Observer assessment

Fifteen of the 54 divers (28%) who had a brain HMPAO-SPECT were found to have an abnormal scan classified as a pattern variant of II–V (table 2). A higher prevalence of abnormality was detected in divers with no history of DCI (10/26 (38%)) compared with divers with a history of DCI (5/28 (18%)). Of the 19 non-diving controls, the result in three cases (15.8%) was categorised as a pattern variant of II–V. There was no significant difference between either of the two diver groups and the controls (χ^2 test, P > 0.05).

Texture analysis

Table 3 shows the MGL values for both diving

Table 2 HMPAO-SPECT findings observer assessment of groups

Pattern variation	Divers with a history of DCI (n = 28)	Divers with no history of DCI (n = 26)	Non-diving controls (n = 19)
I	23	16	16
II	1	1	1
III	1	5	0
IV	1	0	1
V	2	4	1
Total I–V	5	10	3

No significant difference (χ^2 test, P > 0.05).

Table 3 HMPAO-SPECT findings texture analysis (MGL for all groups and age matched pairs)

Group	n	MGL mean (SD)	Age mean (SD)
Divers with a history of DCI****	22	5.99 (0.84)	37.5 (5.2)
Non-diving controls	17	7.06 (1.20)	43.9 (12.2)
Age matched pairs:			
Divers with a history of DCI**	12	5.93 (0.51)	39.3 (5.5)
Non-diving controls	12	6.99 (1.29)	39.3 (6.1)
Divers with a history of DCI*	22	5.99 (0.84)	37.5 (5.2)
Divers with no history of DCI	22	6.51 (0.94)	35.7 (3.9)
Age matched pairs:			
Divers with a history of DCI***	15	6.08 (0.81)	36.9 (3.0)
Divers with no history of DCI	15	6.80 (0.78)	36.9 (3.5)
All divers****	44	6.25 (0.92)	36.6 (4.6)
Non-diving controls	17	7.06 (1.20)	43.9 (12.2)
Divers with no history of DCI	22	6.51 (0.94)	35.7 (3.9)
Non-diving controls	17	7.06 (1.20)	43.9 (12.2)
Age matched pairs:			
Divers with no history of DCI	11	6.29 (1.10)	36.1 (3.8)
Non-diving controls	11	7.09 (1.27)	36.3 (4.0)

*P < 0.05; **P < 0.025; ***P < 0.01; ****P < 0.005; significant difference in MGL between groups; one tailed *t* test.

and non-diving groups. The divers with a history of DCI had a significantly lower MGL result (one tailed *t* test, *df* = 37, *P* < 0.005) than non-diving control subjects and than divers with no history of DCI (one tailed *t* test, *df* = 42, *P* < 0.05). There was no significant difference between divers with no history of DCI and non-divers. Taking both diving groups together (*n* = 44), the MGL for the divers was significantly lower than for the non-divers (one tailed *t* test, *df* = 59, *P* < 0.005).

As the central nervous system undergoes a continuous process of degeneration with age, lower values of MGL would be expected as a person ages. A linear relation between age and MGL could not be shown by regression analysis due to the small group sizes and limited age span of the subjects. However, any significant age difference between groups could influence the results. Comparing divers (*n* = 44) with non-divers (*n* = 17), the groups were found to be significantly different for age; the non-diving control subjects were significantly older, but they had the higher MGL values. Table 3 shows that, with matching for age, divers with a history of DCI were found to have significantly lower MGL values (one tailed *t* test, *df* = 11, *P* < 0.025). There was no significant difference in MGL between divers with no history of DCI and non-divers, when matched for age.

The diving groups were matched, taking into account both age and the extent of diving history, to confirm that the significant difference found between divers with DCI and control divers with no history of DCI was not due to age or an element of diving history. Divers with a history of DCI were found to have significantly lower MGL values than divers with no history of DCI (one tailed *t* test, *df* = 14,

P < 0.01, table 3). Thus the difference between divers with a history of DCI and divers with no history of DCI was supported when matched for age and diving history.

There was no correlation between brain HMPAO-SPECT and the DCS severity index from either visual assessment of image or texture analysis (table 4). Divers who had only had DCS type 1 incidents on the DCS severity index did not have a higher percentage of visually assessed normal scans nor significantly higher MGL values than divers who had had multiple episodes of neurological DCI.

BRAIN HMPAO-SPECT AND DIVING HISTORY

Observer assessment

Twelve air divers and 42 saturation divers (including three divers who had taken part in a saturation diving course but not carried out a commercial saturation dive) had brain HMPAO-SPECT. Only one of the 12 air divers (8.3%) had an abnormal scan whereas 14 of the 42 saturation divers (33.3%) had abnormal scans. Excluding subjects who had only taken part in a mixed gas course, the saturation divers with an abnormal scan (II–V) had carried out a mean of 30 (19) saturation dives with a range of 1–60, compared with 41 (29) with a range of 1–102 for those with a normal scan (variant I).

Correlation values for diving history (table 5) were not significant for any aspect. Thus, there was no apparent association with HMPAO-SPECT. Although the presence of an abnormal brain scan seemed to increase beyond the lowest category of career dives and decompression days in a career, all divers in the highest category with over 2000 career dives or 2000 decompression days were assessed as having a normal HMPAO-SPECT brain scan.

Texture analysis

Regardless of a history of DCI, the MGL for the nine air divers was 6.27 (0.92) with a range of 4.11 to 7.08; whereas the MGL for the 32 saturation divers was 6.29 (0.88) with a range of 4.11 to 8.38. The three divers who had taken the saturation diving course but had not carried out a commercial saturation dive had MGL values of 4.45, 5.26, and 7.50.

Divers with less than the mean number of years of professional diving experience for the whole group (≤ 14 y) had a significantly higher MGL (one tailed *t* test, *df* = 42, *P* < 0.05) than those with more than 14 years experience (table 6). There was also a significant difference in age (*P* < 0.005) between these groups. With ages matched, the signifi-

Table 4 Relation between a history of DCI and HMPAO-SPECT brain scan result

DCI history category	Observer assessment HMPAO-SPECT scan result			Texture analysis HMPAO-SPECT scan result	
	n	Normal (I)	Pattern variant (II–V) (%)	n	MGL mean (SD)
Only DCS type 1	11	9	2 (18)	8	6.06 (0.43)
A single DCS type 2	7	6	1 (14)	6	5.95 (1.30)
Multiple DCS type 2	10	8	2 (20)	8	5.95 (0.85)

No significant difference between any categories at *P* > 0.05.

Table 5 Relation between professional diving history and HMPAO-SPECT brain scan result by observer assessment

Diving history	HMPAO-SPECT scan result	
	Normal (I)	Pattern variant (II-V) (%)
Years of diving:		
< 10	5	3 (38)
10-14	15	6 (29)
15-19	10	5 (33)
≥ 20	9	1 (10)
Career dives:		
< 500	7	1 (13)
500-999	20	10 (33)
1000-2000	9	4 (31)
> 2000	3	0 (0)
Dives/year:		
< 50	16	7 (30)
50-100	18	7 (28)
> 100	5	1 (17)
Decompression days:		
< 550	4	1 (20)
550-999	21	9 (30)
1000-2000	10	5 (33)
> 2000	4	0 (0)
Decompression days/year:		
< 50	8	4 (33)
50-100	25	9 (26)
> 100	6	2 (25)

Table 6 Relation between professional diving history and HMPAO-SPECT brain scan result by texture analysis

Diving history	n	MGL mean (SD)	Age mean (SD)
Years of diving:			
≤ 14*	24	6.48 (0.73)	34.7 (4.0)
> 14	20	5.97 (1.06)	38.9 (4.4)
Age matched pairs:			
≤ 14*	12	6.70 (0.79)	36.7 (2.5)
> 14	12	6.02 (1.14)	36.9 (2.4)
Career dives:			
< 600*	13	6.51 (0.85)	34.9 (3.4)
600-1000	17	6.34 (0.87)	35.7 (3.9)
> 1000*	14	5.90 (0.99)	39.3 (5.5)
Age matched pairs:			
< 600	9	6.38 (0.78)	36.2 (3.1)
> 1000	9	5.89 (1.02)	36.7 (3.4)
Dives/year:			
< 50	17	6.51 (0.77)	36.9 (3.6)
50-100	22	6.16 (0.94)	36.0 (4.7)
> 100	5	5.75 (1.21)	38.6 (7.5)
Decompression days:			
< 700	14	6.49 (0.82)	35.2 (3.7)
700-1200	18	6.20 (0.98)	35.7 (3.6)
> 1200	12	6.05 (0.96)	39.6 (5.9)
Age matched pairs:			
< 700	8	6.35 (0.81)	35.8 (3.5)
> 1200	8	5.95 (1.08)	36.4 (3.5)
Decompression days/year:			
< 60**	17	6.52 (0.74)	36.6 (3.6)
60-100	20	6.23 (0.96)	36.4 (4.8)
> 100**	7	5.67 (1.00)	37.3 (6.7)

*P < 0.05; **P < 0.025; significant difference in MGL between groups; one tailed *t* test.

Table 7 Relation between MGL and previous non-diving neurological insult

Non-diving neurological insult	n	MGL mean (SD)	Age mean (SD)
Exposure to head injury or toxic fume (HI/TF):			
*Category 0-1	20	6.04 (0.91)	38.8 (5.1)
Category 2-3	5	6.54 (0.79)	34.4 (4.3)
*No HI/TF	19	6.42 (0.96)	34.9 (3.1)
Age matched pairs:			
Category 0-1	11	5.91 (1.07)	37.5 (2.4)
No HI/TF	11	6.53 (1.12)	36.5 (2.3)
Misuse of drugs:			
Drug user	21	6.06 (0.69)	37.1 (4.3)
Non-user	23	6.42 (1.08)	36.1 (5.0)

*Significant difference in age between groups two tailed *t* test, P < 0.05.
Category 2-3: group size too small to age match.

cant difference in MGL of divers with greater or less than 14 years of professional diving experience was confirmed (one tailed *t* test, df = 11, P < 0.05).

Divers with less than 600 dives in their career had a significantly higher MGL than divers with more than 1000 dives in their

career (one tailed *t* test, df = 25, P < 0.05). However, these groups are significantly different in age (P < 0.025) and with ages matched, no significant difference in MGL for career dives was found (table 6). As the number of dives in a year increased, there was a decrease in MGL. However, there was no significant difference between the mean MGL for divers with less than 50 dives in a year and those with more than 100 dives in a year. Similarly, there was no significant difference in age between these groups.

The MGL seemed to decrease as the number of decompression days in a diver's career increased but there was no significant difference in MGL between divers with more than 1200 decompression days in their career and those with less than 700. There was a significant difference in age between these two groups (P < 0.025) and the lack of a significant difference in MGL for number of decompression days in a career was confirmed when ages were matched (table 6). As decompression days in a year increased, MGL decreased and there was a significant difference (one tailed *t* test, df = 22, P < 0.025) between divers with less than 60 decompression days in a year and divers with more than 100 decompression days in a year (table 6). There was no significant difference in age between these two groups.

NON-DIVING NEUROLOGICAL INSULT

Observer assessment

Twenty one divers did not report previous possible neurological insult in the form of head injury or exposure to toxic fume. Six (29%) had an abnormal HMPAO-SPECT brain image. This compared with six of 23 divers (26%) who had an abnormal scan and a neurological insult classified as clinically minor and three of 10 divers (33%) with an abnormal brain scan and who were categorised as having had a major neurological insult. However, of these 10 divers, only four had a head injury or exposure to toxic fume classified as clinically highly relevant and all had a normal scan.

There would seem to be no difference between those who misused drugs and those who did not, with the presence of a pattern variant in the scan. For non-users, eight of 29 (27.6%) were assessed as having a pattern variant compared with seven of 25 (28.0%) for misusers of drugs.

Texture analysis

Of the 44 divers, 25 reported a head injury or exposure to toxic fume, of which 20 were assessed as being clinically minor. There was no significant difference in MGL for extent of head injury or exposure to toxic fume (table 7). Most people in the group of subjects with clinically minor head injury or exposure to toxic fume, were in the older age range.

Forty eight per cent of divers reported misuse of drugs but did not have significantly lower MGL values than non-users (table 7). Four divers reported current or previous use of hard drugs (including heroin and cocaine) and

they had an MGL of 6.44 (1.13) and were older than others in the drug users category with a mean age of 40.8 (6.3) years.

Discussion

Although there was no significant difference between any of the three groups in the observer assessments of brain HMPAO-SPECT, 15 of the 54 commercial divers (28%) who participated in this investigation had scans which were classified as being outside normal limits and this indicates a higher level of abnormality than was found in the non-diving controls (15.8%). When divers with and without history of DCI were compared, a higher prevalence of abnormality was detected in divers with no history of DCI (38%) compared with divers with a history of DCI (18%), although this difference was not significant. This finding is at variance with that of Macleod *et al* who used a voxel by voxel method of analysis and reported that 26 (52%) of their 50 divers with a history of DCI were assessed with cerebral perfusion deficits, whereas deficits were detected in only six (33%) of 18 divers with no history of DCI.¹⁷ They also reported a significant difference in results between divers with a history of DCI and the non-diving controls. Of the 40 non-diver control subjects in that study, seven (18%) had cerebral perfusion deficits which is comparable with 3/19 (15.8%) in this study.

Several findings relating to observer assessment of brain HMPAO-SPECT have led to the validity of this method of assessment being questioned. These include the lack of correlation between the visual assessment of brain scans with a history of DCI; the finding that divers with no history of DCI were assessed as having a higher percentage of patterns different from a normal scan than divers with a history of DCI; and an apparent lack of correlation between any measure of diving history and the assessment of the brain scan. It also highlights the conflicting reports found in the scientific literature over the use of brain HMPAO-SPECT in the study of DCI and suggests that a more quantitative or objective measure of assessment is required.

The introduction of analysis of the HMPAO-SPECT brain images by first order texture measurement has considered this requirement. It has shown that divers with a history of DCI had a significantly lower MGL—that is, a patchier image—than both divers with no history of DCI and non-divers. No significant difference was found on comparing the MGL of divers who had only had episodes of DCI involving limb pain or the skin and those who had experienced multiple episodes of neurological DCI. This may simply be a reflection of the lack of exploration of the use of a DCI severity index in this study.

There was no significant difference in MGL between divers with no history of DCI and non-diving controls. However, taking the groups as a whole, the non-diving controls were significantly older and yet had a higher MGL, suggesting that diving activity may have

had an effect on brain image, reflecting nervous tissue damage. This was supported by the finding that divers with more than 14 years of professional diving or with more than 100 decompression days in a year, regardless of history of DCI, had a significantly lower MGL. This is an indication that exposure to extensive diving has an effect on brain HMPAO-SPECT and suggests that there are alterations in regional cerebral blood flow. This may have important ramifications for the divers in later life. Further extrapolation to investigate the dependence of MGL on age and diving could not be carried out in this study due to the limited age ranges of divers and non-diving control subjects.

On comparison of MGL of air and saturation divers, no difference was noted between the groups. The finding of a difference in observer assessment of brain images in this area of diving history is thought to be a source of unreliability; this is supported by the findings within the saturation diving group, in which those assessed as having an abnormal scan had carried out fewer saturation dives. The possible influence of potential contributory factors was examined; such factors included previous non-diving neurological insult in the form of head injury, exposure to toxic fume, or misuse of drugs. No significant differences were found. Although we recognise the small subject numbers in some groups, it is assumed that such potential contributory factors have had no influence on the findings reported here.

Analysis of brain HMPAO-SPECT by an objective measure of texture has indicated perfusion differences in age matched divers with a history of DCI compared with non-divers. There is also an indication that diving itself has an effect on texture measurement, implying that it has caused subclinical nervous tissue damage. This suggests that brain HMPAO-SPECT incorporating objective and consistent methods of analyses of images may have a part to play in the study of the long term health effects of diving and decompression illness especially as the diving population ages.

We are grateful to the volunteers who participated in this study; and to Mr A Wilson for his valuable assistance with the statistical analysis.

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Correspondence and editorials

Occupational and Environmental Medicine welcomes correspondence relating to any of the material appearing in the journal. Results from preliminary or small scale studies may also be published in the correspondence column if this seems appropriate. Letters should be not more than 500 words in length and contain a minimum of references. Tables and figures should be kept to an absolute

minimum. Letters are accepted on the understanding that they may be subject to editorial revision and shortening.

The journal also publishes editorials which are normally specially commissioned. The Editor welcomes suggestions regarding suitable topics; those wishing to submit an editorial, however, should do so only after discussion with the Editor.

interpretation, the other main topic is epidemiology and those working in health and safety at work.

The meeting will be of particular interest to representatives of authorities responsible for the establishment of occupational exposure limits or the definition of lists of occupational diseases, medical inspectors of workplaces, occupational physicians, safety engineers, representatives of the social groups, the social security institutions, and occupational epidemiologists.

Further information from: the Office for International Relations and Conferences, Adalbert-Stifter-Strasse 65, A-1200 Vienna, Austria. Tel. +43-1-33 111 - 537, Fax +43-1-33 111 469 email: presse@auva.or.at

International Symposium on Good Occupational Health Practice and Evaluation of Occupational Health Services. 8-10 June 1998. Hanasaari Cultural Centre, Espoo, Finland

The symposium is organised by the Finnish Institute of Occupational Health (FIOH), the Ministry of Social Affairs and Health, Finland, and the International Commission on Occupational Health (ICOH), Scientific Committee on Health Services Research and Evaluation in Occupational Health.

The aim of this symposium is to stimulate and to promote the international exchange of experiences on achieving good occupational health service practices and to promote development of concepts, strategies, and methodology in evaluating occupational health services (OHS). Topics included in this area are quality and effectiveness, multidisciplinary, flexibility and good practices with regard to needs of clients and consumers' demands, research on OHS as an advisory service contributing to rational decision making on national, regional, and local levels, as well as on the enterprise level or the OHS service unit level, and the interaction between scientific institutions, service providers, and the health service market. Considering the broad scope of the subject matter of the symposium, issues related to world wide trades and working life are also included.

The programme will include plenary lectures, oral and poster presentations, as well as panel discussions. The working language of the Symposium is English.

Topics include:

- Good occupational health practice, focusing on workplace evaluation and systems evaluation

Keynote lecture: Global trends and developments in occupational health services (objectives and inputs); Jerry Jeyaratnam, ICOH, Singapore

Keynote lecture: Good occupational health practices: Concepts and criteria; Frank van Dijk, The Netherlands

- Evaluation

Keynote dialogue: Strategies and methods for scientific evaluation of occupational health services; Peter Westerholm, Sweden and Kaj Husman, Finland

- Future perspectives

Keynote lecture: Challenges of occupational health services in changing societies and working life; Jorma Rantanen, Finland

- Other topics related to good occupational health practice and occupational health service evaluation

Further information from: Symposium on Good Occupational Health Practice and Evaluation of Occupational Health Services Finnish Institute of Occupational Health Symposium Secretariat, Inkeri Haataja Topeliuksenkatu 41 a A, FIN-00250 Helsinki, Finland; telephone: Int.+358-9-474 7470; fax: Int.+358-9-474 7548; e-mail: Inkeri.Haataja@occuphealth.fi www: http://www.occuphealth.fi/tiedotus

CORRECTIONS

Correlation between ^{99m}Tc-HMPAO-SPECT brain image and a history of decompression illness or extent of diving experience in commercial divers TG Shields, PM Duff, SA Evans, HG Gemmell, PF Sharp, FW Smith, RT Staff, SE Wilcock (1997;54:247-253).

The bottom row of table 2 should read Total II-V, not I-V. The address for S E Wilcock should be only the Hyperbaric Research Unit, Robert Gordon University, School Hill, Aberdeen AB9 1FR.

Cancer mortality among magazine printing workers Danièle Luce, Marie-France Landre, Thierry Clavel, Isabelle Limousin, Sylvie Dimerman, Jean-Jacques Moulin (1997;54:264-7)

Page 266 column 2 line 4 should read <1 µg, not <1 g. Also in table 2 for oesophagus <1970, the expected number should be 0.20, not 2.20.

BOOK REVIEWS

Mechanisms of fibre carcinogenesis: IARC Scientific Publications No 140. Edited by AB KANE, P BOFFETTA, R SARACCI, JD WILBOUR. (Pp 135; £45). 1996. Lyon: IARC. ISBN: 92832-2140-0.

This book represents a collection of reviews written by the participants in a workshop on the mechanisms of fibre carcinogenesis, held at the IARC in Lyon on 9-11 January, 1996. The goals of the workshop were twofold; to review and discuss the current knowledge on the mechanisms of fibre carcinogenesis, and to use this knowledge in the assessment of carcinogenic risks to humans or animals.

The primary outcome of the workshop was the consensus report, which is presented in the first part of the book, and was agreed by all the workshop participants. This report brings to light a surprising number of weaknesses and data gaps in the available literature on fibre characterisation, genotoxicity, cell proliferation or activation, and animal

studies. A prime example of such shortcomings is the general lack of information on the characterisation of fibre dose—that is, numbers, dimensions, surface area, chemistry, durability, and biopersistence—for most in vitro and in vivo studies. The report also discusses the relevance of mechanistic data from in vitro and in vivo assays for the evaluation of carcinogenic risk to humans and concludes with several recommended experimental studies which would provide additional data for the future assessment of fibre carcinogenicity.

The remainder of the book focuses on various aspects of mineral fibre carcinogenicity which were outlined in the consensus report, and such reviews express the opinions of their authors. Briefly, the paper by Kane provides a good discussion of the proposed five mechanistic hypotheses for fibre carcinogenesis. Fubini follows up on these hypotheses by examining the interactions between fibres and cells through the analysis of fibre parameters such as crystallinity, micromorphology, elemental analysis, solubility, and adsorption, which are often not considered by most investigators. The report by Jaurand provides cautious consideration to the limitations and feasibility of mutation and cell transformation assays for investigating the mechanistic effects of fibres. Topics presented by Driscoll focus on processes which may contribute to the neoplastic effects of various fibres and current issues such as signal transduction pathways, oxidative stress, antioxidant mechanisms, and protooncogene expression. Donaldson describes in detail the role of reactive oxygen species, cytokines, and growth factors in preneoplastic and fibrotic changes. The advantages and disadvantages of inhalation, intratracheal instillation, and intracavitary injection are reviewed by Oberdörster. The final review, by Davis, discusses the interactions of inhaled particulate matter along with fibres and the potential effects of mixed doses on fibre pathogenicity.

Overall this book is a collection of concise and up to date reviews on the subject of fibre (mainly asbestos) carcinogenesis. It is generally readable, clear, and informative. Its comprehensive tables and references provides a very good introduction for newcomers to the subject, as well as being an excellent resource for examination candidates. Unfortunately, the most appropriate readers (students) will be unable to afford its high price. The sections in the reviews on recommended experimental studies and unanswered questions are worthwhile to the professional audience. These sections state clearly the directions that research should take to close gaps in data and strengthen current information. There are several similar books on the market today which deal with the health effects and actions of mineral dusts; this book will be of interest to those investigators who work predominately with asbestos fibres.

KELLY ANN BÉRUBÉ

Immunopathology of Lung Disease

Edited by RICHARD L KRADIN, BRUCE WS ROBINSON (pp 578; £87.99) 1997. Oxford: Butterworth-Heinemann. ISBN: 0-7506-9282-0.

This is the first comprehensive text book on the immune responses of the lung in health and disease since *Immunology of the Lung and Upper Respiratory Tract*, edited by John Bienstock, was published in 1984. The book