

# **CASE REPORT**

## **Fitness to return to Submarine Escape Training Tank training following acute neurological decompression illness from an arterial gas embolism.**

M. HICKEY<sup>1</sup>, C. FOSTER<sup>1</sup>, J. LLOYD<sup>2</sup>, W. NORRIS<sup>2</sup>, D. WHITEHOUSE<sup>1</sup>

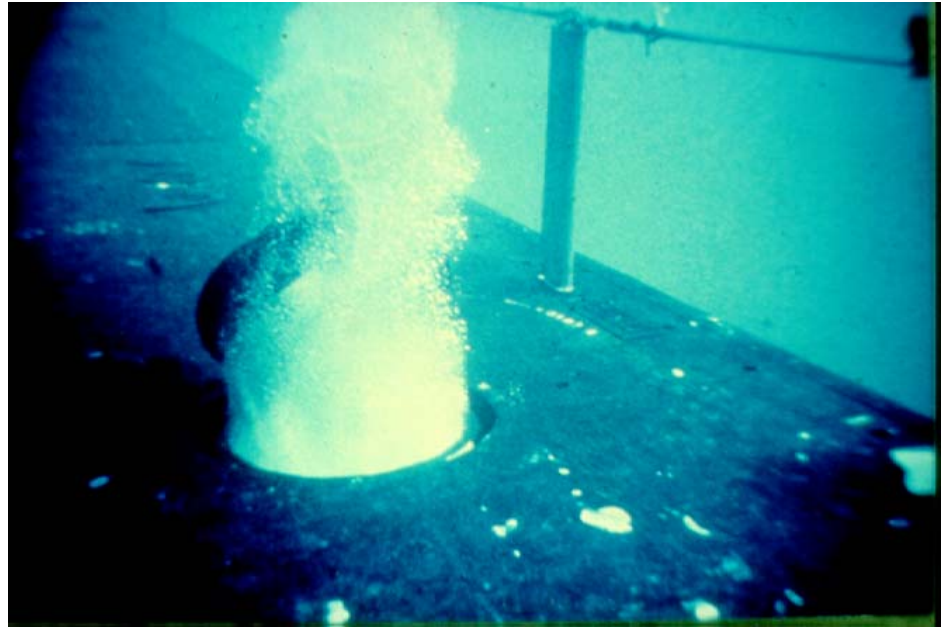
<sup>1</sup>Institute of Naval Medicine, Alverstoke, Hampshire PO12 2DL, UK

<sup>2</sup>Submarine Escape Training Tank, Fort Blockhouse, Gosport,  
Hampshire PO12 2AB, UK

## **Abstract**

All Royal Navy servicemen aspiring to become submariners are required to complete SETT training, which requires hyperbaric exposure in the form of buoyant ascents and a submarine escape suit – hooded ascent. Historically, trainees incurring an AGE during the training do not return to complete the training, regardless of their desire or symptom resolution. Following an 18-metre buoyant ascent, a 23 year-old trainee incurred acute neurological DCI from an AGE. He was immediately treated with hyperbaric oxygen (HBO) and achieved full recovery of all deficits during the single treatment. In this particular case, the trainee's AGE was unique in that he displayed excellent technique in performing the buoyant ascent. Owing to the unexplained nature of the trainee's AGE, concern was raised on permitting him to finish his final pressurisation (a submarine escape suit - hooded ascent), which was ultimately required for him to become a submariner. Should the trainee's history of an “undeserved” AGE in a buoyant ascent render him unfit for a subsequent similar pressure exposure? The trainee was keen to complete the training. He received a thorough medical review and examination, which included imaging of the heart and lungs. Despite the unexplained nature of the AGE, the diving medical officer (DMO) found him fit to finish his final hooded ascent. Seven weeks after the initial incident, the trainee successfully completed the final hooded ascent without any ill effects. Little exists in the medical literature on “return to diving / pressurisation” training following DCI from an AGE. This case may serve as single reference point in assisting a physician to consider the various aspects in returning a trainee to a “fit to dive” status.

# Escape from a submarine

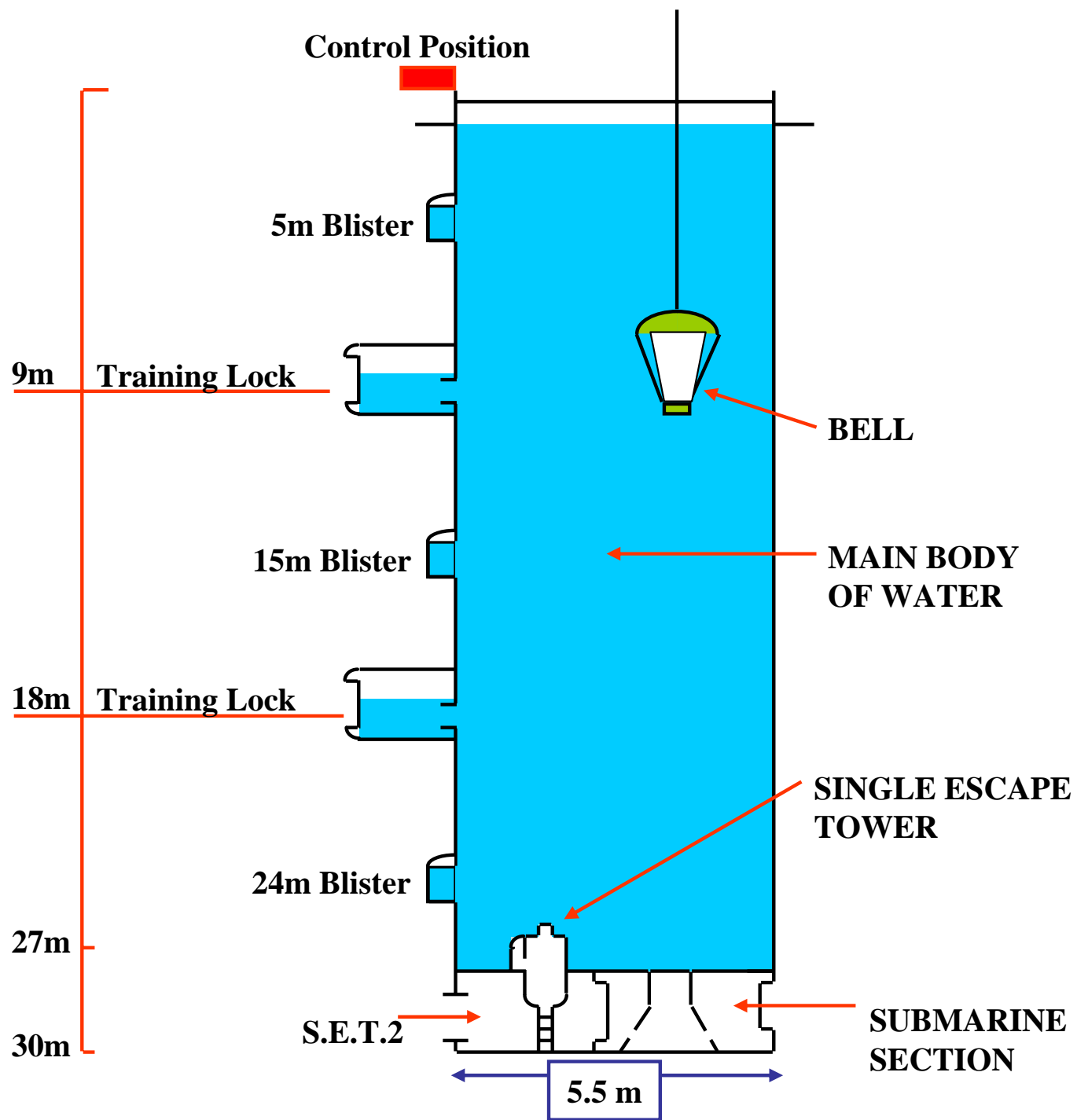


**Submarine  
Escape  
Training  
Tank**

**Fort Blockhouse  
Gosport  
Hampshire  
UK  
PO12 2AB**

**Tel: 44 (0) 23 9276 5108**







# Medical Screening for SETT Training

SETT Training involves multiple hyperbaric exposures of up to 4 bar with a rapid decompressions. Therefore, particular attention must be paid to the respiratory and ENT systems, as well as other conditions which may prejudice the safety of hyperbaric exposure.

# Medical Requirements for SETT Training

- Physical Examination
- Dental Examination
- Urine Test
- Spirometry
- Audiometry
- Chest Radiograph
- In date for a passed service fitness test
- Full blood count (if clinically indicated)
- ECG (if clinically indicated)



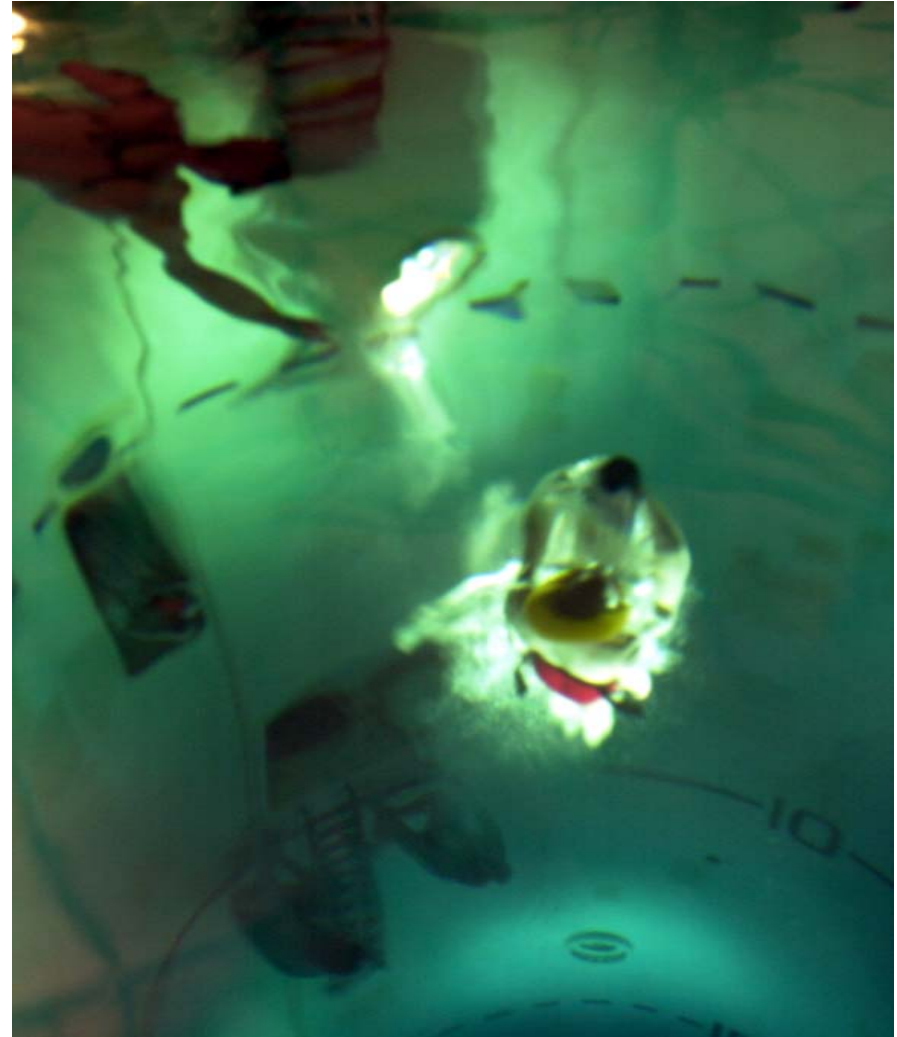
# Buoyant Ascents (day 4)



- Two 9 metre ascents
- One 18 metre ascent
- Lock is flooded and pressurised
- Door opens
- Trainees exit at 1 minute intervals, exhaling all the way to the surface
- 9 metre ascent rate: 1.2 m/s
- 18 metre ascent rate: 1.5 m/s



# Buoyant Ascents (day 4)



- Between each buoyant ascent, trainees stand on the white line for medical observation
- The surface interval between each buoyant ascent (pressurisation) is a minimum of 15 minutes
- The combined bottom time for the 3 ascents is usually  $< 30$  minutes



# Submarine escape suit - hooded ascent (day 5)



- Single-man escape trunk
- 28 metre depth
- Trunk is flooded and quickly pressurised
- Trunk hatch opens
- Trainees instructed to breath normally on ascent (inhale and exhale)
- Ascent rate 2.6 m/s
- Usually < 1 minute of total pressure exposure





**Bells crew waiting for equalisation**



**Hatch opening**



**Out you come – checked – speak (shout)**



**-hooked on – released -**

**Breathing normally all the way up**





# Submarine escape suit - hooded ascent (day 5)



# Consequences of failing to complete SETT training

- An initial trainee will not become a submariner if he does not complete SETT training
- SETT training waivers are NOT granted for initial trainees wishing to become submariners
- SETT training waivers are only granted for existing submariners going through requalification training

# The Case

- 23 year-old aspiring submarine engineering officer
- History of childhood asthma dictated pulmonary function tests (PFTs) before being cleared for SETT training (1)
- All other medical requirements were satisfactorily met

# PFT results (summary)

Parameter	Predicted	Actual	%
FVC (litres)	5.26	5.44	103
FEV1 (litres/sec)	4.44	4.72	108
FEV1/FVC (%)	83	87	
FEF 25-75%	5.08	5.70	112
PEF (litres/sec)	10.00	11.51	115
TLC (litres)	7.14	6.90	97
RV (litres)	1.65	1.08	65
RV/TLC (%)	24	16	
VA (litres)	7.14	6.29	88
Parameter	Resting Value	Actual	% change
FEV1 immediately post-exercise	4.72	4.99	6
FEV1 ten minutes post-exercise	4.72	4.77	1
FEV1 post beta-agonist challenge	4.44	4.79	1
FEF 25-75% immediately post-exercise	5.70	6.72	18
FEF 25-75% ten minutes post-exercise	5.70	5.68	0
FEF 25-75% post beta-agonist chall.	5.08	5.77	1



# Trainee commences SETT training

- PFT results well within satisfactory values
- Overall, found FIT to commence initial SETT training
- Commences training 6 months after PFTs
- Day 4: Successfully completes all buoyant ascents with satisfactory technique

1 <sup>st</sup> 9 metre pressurisation bottom time*		14 min 30 sec
	surface interval time	15 min 5 sec
2 <sup>nd</sup> 9 metre pressurisation bottom time		11 min 0 sec
	surface interval time	20 min 25 sec
18 metre pressurisation bottom time		6 min 0 sec
total bottom time combined		31 min 30 sec

\* Owing to an ear squeeze in one of the trainees, pressurisation to depth took several minutes longer than expected

# After completing 18 metre buoyant ascent

- Trainee noted numbness and tingling on left foot 1 minute after surfacing and did not report it
- Whilst attempting to remove lifejacket 10 minutes after surfacing, trainee realised he could not move his right arm and alerted staff
- Diver medic assessed trainee with motor deficits to right arm and left leg (abnormal gait)
- DMO summoned, trainee placed on 100% oxygen and assisted into recompression chamber
- Presumptive diagnosis of acute neurological DCI made (cerebral arterial gas embolism)

# Treatment for Trainee

- RN Table 62 (USN Table 6) immediately initiated
- Initial neurological exam by DMO: gross right upper extremity weakness and left foot numbness / tingling (leg weakness resolved)
- After 2nd 20-minute oxygen extension at 18 metres, normal neuro exam
- No recurrence of symptoms following treatment
- CXR rules out gross pulmonary barotrauma
- Trainee rendered UNFIT to complete final training day



Recompression Chamber at top of SETT

# Story Over? No!

- Trainee strongly desires to serve as a submariner and wants to finish training (one final submarine escape suit - hooded ascent from 28 metres remaining)
- DMO considers request and medically re-evaluates trainee
- 4 days after: Echocardiogram (non-bubble contrast) normal (no obvious trans-septal flows)
- 26 days after: High resolution CT scan of chest normal (no air-trapping)
- 1 month after: Chest consultant reviews PFT results. Trainee found to be FIT from respiratory perspective
- DMO decides to find trainee fit to complete last ascent



# What Happens?

- DMO discusses with trainee that he is medically FIT to continue; however, he is possibly at an unknown degree of greater risk for DCI (AGE) in the final ascent
- Trainee accepts; desires to continue
- Trainee makes the last submarine escape - hooded ascent from 28 metres seven weeks after the initial incident
- Successfully completes the ascent without any ill-effects
- Starts his career as a Royal Navy Submarine Engineering Officer

Was it the correct fitness decision?  
Should the trainee's history of an  
“undeserved” AGE in the buoyant  
ascent render him unfit for a  
subsequent similar pressure exposure?

## **Discussion**

- Aetiology and Diagnosis
- Quantification of Risk
- Acceptability of the Risk

# Aetiology and Diagnosis

- CAGE associated with rapid ascents (2)
  - Neurologically incapacitated shortly after surfacing
  - Low gas burden (combined bottom time 32 minutes. At 18 metres, 55 and 60 minutes permitted per RN and USN tables, respectively)
- Radiologic evidence usually not present (less than half of scuba divers with an AGE had PBT) (3)
- “Unequivocal confirmation not possible” (2)
- No evidence of gross PFO, although gas burden low. Possibly not even related if PFO existed

# Aetiology and Diagnosis

- HRCT found to be normal
  - Rule out pathology (cysts and blebs) and assess future fitness to dive (4)
- PFTs acceptable, although little evidence to suggest any spirometric or plethysmographic value is a definitive risk factor for pulmonary barotrauma (AGE)
- There is a statistically significant association with a low FVC and pulmonary barotrauma in SETT training; however, insufficiently specific for a low FVC to serve as exclusion criteria for SETT training (5)



# Quantification of Risk

- Maximum combined DCI (definite or possible) with or without barotrauma in initial trainees from 1975-1993 (6)
  - 18 metres: 0.5 per / 1000 ascents
  - hooded ascent: 0.46 / 1000 ascents
- Or is this trainee's risk 1 in 3 ascents
- Is the trainee's DCI “deserved” or “undeserved”
  - No technique problems
  - Are all rapid ascents “deserved”?
  - Technique not as much of an issue on hooded ascent

# Quantification of Risk

- Consider the actual / possible severity
  - 1 death since 1975
  - This trainee with focal neurological symptoms, but fully resolved after treatment; trainee fit and well
  - SETT RCC chamber mitigates risk but should not be used to mitigate increased individual risk
- Unprecedented case: no known previous DCI cases permitted to continue with SETT training

# Acceptability of Risk

- Serviceman: strongly desired to finish training.
  - Fully accepted he was “possibly” at an unknown degree of greater risk for DCI (AGE) in final ascent
- DMO: employed by the Ministry of Defence (MoD)
  - Expected to not needlessly find “unfit” (MoD needs submariners), but also expected to protect the MoD
  - DMO to make a life-altering decision, however, must reasonably protect patient
- MoD: accepts the risk on behalf of the DMO
  - Currently, Royal Navy drafting men for service (non-volunteers)
  - Would not be pleased to be named in a lawsuit
  - Severe adverse outcomes could influence future of SETT

# Questions

- Would you have found this SETT trainee FIT or UNFIT?
- How would you relate this to a new diver (professional or recreational) incurring “undeserved” DCI (from an AGE).
- How about if the diver ascended rapidly, but not uncontrolled (deserved)?
- Pending a subsequent normal medical work-up, would you find that diver FIT to continue diving?

# Conclusions

- DMO ultimately relied on a completely normal medical evaluation of the trainee, coupled with the trainee's strong desire to become a submariner
  - The trainee would only have to complete one more single exposure
  - Rapid ascents run the risk of an AGE, no matter how much the risk is mitigated
- Despite a good outcome, this is not to say the DMO's decision was the “right” fitness decision
- Still much to learn about the pathophysiology of pulmonary barotrauma, AGEs and DCI



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