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MEDICATIONS FOR THE TREATMENT OF MOTION SICKNESS DURING EVACUATION, ESCAPE AND RESCUE OFFSHORE

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SUMMARY

A high incidence of seasickness has been recorded amongst survivors of accidents occurring offshore, whether in lifeboats or in the water. Illness is prevalent in relatively calm seas as well as conditions of severe wind and wave. When considering the occupants of totally enclosed motor propelled survival craft (TEMPSC), then the shape and design of the vessel, the lack of visual cues, the lack of forward facing seats and head restraint, the smell, and the view of others being sick are all factors which exacerbate the problem.

The majority of drugs used in the treatment of nausea and vomiting are given in advance, to prevent the development of symptoms. The timescale of emergency evacuations allow little time for preparation. Drugs are thus required which will have a rapid onset of action, in an attempt to prevent vomiting. Treatment of existing seasickness is also important, to reduce the risks from the debilitating effects of illness and dehydration.

Of the anti-emetic agents currently available, scopolamine is thought to be the most effective drug, both for the prophylaxis and treatment of seasickness. To achieve therapeutic levels quickly, and then maintain the treatment, a combination of preparations are indicated; an initial dose given by buccal tablet or injection followed by a transdermal patch to ensure long-term effectiveness.

CONTENTS

1. INTRODUCTION

Numerous studies have been undertaken to evaluate the risks involved in evacuation, escape and rescue (EER) from offshore installations. While much consideration has been given to the mechanical aspects of EER, little is known about the human factors and in particular, the physiological and psychological stresses experienced by the occupants of totally enclosed motor propelled survival craft (TEMPSC). Accident enquiries sometimes provide important indications and anecdotal evidence of the problems of survival encountered in emergency situations. Such reports have for example shown that the incidence of motion sickness is high even in moderately calm seas (Landolt et al, 1992). Rescue and transfer out of the TEMPSC is potentially one of the most dangerous stages of EER in severe weather, such that it may sometimes be safer to leave personnel within the closed-down TEMPSC, to await more favourable conditions. However, the effects of spending long periods of time within a TEMPSC have not been researched. The worst scenario is likely to involve severe weather which does not abate for some days, high ambient temperatures, and a TEMPSC loaded to full capacity with occupants dressed in insulated survival suits. In such a situation, motion sickness could lead to severe dehydration and debilitation which would hinder rescue attempts.

In a study of the survivability of occupants of TEMPSC (Light & Coleshaw, 1993) under relatively mild weather conditions by offshore standards, 49% of the occupants reported motion sickness within the 30 minutes after departure, resulting in an early cessation of the trial on the basis of ethical considerations. Further reference will be made to this study later. However, two important conclusions of this trial were that there was:

- a requirement for rapidly acting, easily absorbed anti-emetic drugs;
- a requirement for adequate supplies of replacement fluids.

Bohemier (1993) suggested that seasickness may be a contributory factor in death after aircraft ditching in cold water. A survey is currently being conducted in Canada to assess the incidence of seasickness in aircrew trainees carrying out survival training at sea. Bohemier highlighted the need for more effective treatment of motion sickness.

An excellent review of seasickness in occupants of totally enclosed motor propelled survival craft (Landolt & Monoco, 1989) covered the problems of drug therapy, suggested a possible solution, but also recommended that further research was needed to provide a long-term solution for the treatment of motion sickness in rig-abandonment evacuees.

It is the aim of this review to assess the range of anti-emetic medications currently available and suitable for the treatment of motion sickness in personnel during evacuation, escape and rescue from an offshore installation. Particular emphasis will be placed on routes of delivery, time of onset, duration of action and unwanted side-effects of the drugs.

2. AETIOLOGY OF MOTION SICKNESS

Motion sickness and more specifically seasickness is clinically manifested as nausea and vomiting, associated with secondary symptoms of stomach awareness, drowsiness and sometimes salivation. Other signs include pallor, changes in respiratory rate and heart rate. Incidence of seasickness is reported to be higher in women compared to men (Lawther & Griffin, 1988) with a ratio of 5 : 3, while incidence is thought to decrease gradually with age, being highest in the under 15 years age group. External factors such as smell (diesel fumes) and the sight and sound of others suffering all play a part.

2.1 NEURAL MISMATCH HYPOTHESIS

Motion sickness occurs when the brain receives conflicting information regarding the position and orientation of the body with respect to its surroundings, often described as neural mismatch. Various sensory organs are involved:

- Eyes, perceiving visual information;
- Semi-circular canals in the ears, perceiving angular acceleration in all directions;
- Otolith organs in the ears, perceiving linear accelerations of the head and the direction of gravity relative to the head;
- Other proprioceptors and mechanoreceptors, sensing movement and position of other parts of the body.

The neural mismatch hypothesis (Reason & Brand, 1975) is a model used to explain why the reactions occur when they do and why they diminish with continued exposure. The hypothesis states (Pingree, 1989) that "in an unfamiliar motion environment, the information being relayed to the brain by these sensors is mutually conflicting and at variance with past experience as represented by a neural store of expected signals". It is proposed that a comparison occurs between the current sensory information entering the brain, and a memory store of previous experiences which constitutes the 'normal' situation. The response to this mismatch is characterised by the set of signs and symptoms of motion sickness described earlier. Neural mismatch is possible between the eyes and the vestibular system, and between the two components of this system, the otoliths and the semi-circular canals (Pingree, 1989).

The neural mismatch theory also provides an explanation for adaptation. As the experience of motion continues, the memory store is gradually updated, such that the current motion environment is recognised as being 'normal'. As this update progresses, so the degree of mismatch decreases and the individual becomes accustomed to the new environment. Adaptation can take up to 4 days to take full effect, although there is considerable inter-individual variability.

The reverse mismatch effect is also possible when an adapted individual returns to a non-motion environment. The susceptible individual experiences a persistent sensation of rocking and swaying, on returning to land. This effect, known as "mal de debarquement" is usually short-lived (Murphy, 1993).

2.2 SHIP AND BODY MOTION

The relationship between ship motion, body motion and seasickness has been well described (Lawther & Griffin, 1986; Griffin, 1991). Vessels may move in three translational axes (x-axis: fore and aft motion; y-axis: lateral motion; z-axis: vertical motion / heave) and three corresponding rotational axes (roll, pitch and jaw). The motion of the body will correspond to the motion of the vessel if the person is standing or seated facing forwards. However, if the person is seated sideways on to the vessel, then roll of the ship will be experienced as pitch (body tilting forwards or backwards). This interaction will also depend on whether the individual is upright or recumbent. Lawther and Griffin (1986) showed a good correlation between vertical (z-axis) motion and incidence of illness and vomiting in cruise ship passengers.

The effects of motion will also be influenced by the size and shape of the vessel, with motion minimal in a large stabilised cruise ship, and potentially most severe in a small flat-bottomed vessel such as the TEMPSC, which rides every wave. Wiker et al (1979) reported a higher incidence of illness in a 29 m patrol craft than in a 27 m twin-hull boat. Incidence of motion sickness was related to low frequencies of motion and high magnitudes of motion. Maximum incidence of motion sickness in response to vertical oscillation occurs at a frequency of 0.2 Hz (O'Hanlon & McCauley, 1976), regardless of the motion intensity. Ship oscillatory motion occurs at frequencies ranging from 0.1 to 0.5 Hz (Pingree, 1989).

3. THE PROBLEM OFFSHORE

3.1 ACCIDENTS INVOLVING TEMPSC

Little information is available regarding the occurrence of motion sickness in TEMPSC due to the thankfully limited number of cases where TEMPSC have been used in a real emergency situation. However, five recent disasters in UK, Norwegian and Canadian waters, have provided varying amounts of information regarding the incidence of motion sickness in TEMPSC, pre-disposing factors, use of medication and its effectiveness. These disasters and the resulting accident reports have been extensively reviewed by Landolt and Monaco (1989) and Landolt et al (1992). The relevant facts from these cases are summarised below.

3.1.1 Alexander Keilland

In this accident, where a mobile semi-submersible unit collapsed and capsized, only 89 of the 212 personnel survived. Of the survivors, 59 managed to escape in a TEMPSC, most suffering from hypothermia and seasickness on rescue. Of those who died, from drowning and hypothermia, there is no evidence that seasickness contributed to their deaths. There is also no record that any of the personnel took any medication for seasickness.

3.1.2 Ocean Ranger

The Ocean Ranger semi-submersible drilling unit capsized and sank in seas of 13-18 m and a water temperature of -1°C. All 84 men onboard died. Some personnel did manage to evacuate the rig in a damaged TEMPSC, but following capsize of the TEMPSC during the rescue attempt, none were rescued. There is thus no evidence regarding whether any of the victims were suffering from seasickness or whether medication had been taken.

3.1.3 Vinland

When a 'gas blowout' occurred on the semi-submersible drilling rig, the Vinland, in seas of 2-3 m, 76 personnel safely evacuated the rig in two 50-man TEMPSC. Two hours after the evacuation the TEMPSC motored into the lee of an island, such that when rescue occurred after 8 hours, weather conditions had moderated. It was reported that during the time in the TEMPSC, 90% of the occupants were violently ill from seasickness, many during the first 30-60 minutes. A 'chain reaction of vomiting' was observed by one survivor. Individuals were reported to have been suffering from fatigue and indecisiveness in their deliberations during this period of illness. However, the incidence of seasickness had subsided by the time of rescue allowing all survivors to perform self-rescue and climb scramble nets. This improvement is perhaps due to a combination of moderating weather and adaptation to the motion.

All of the survivors of the Vinland accident took medication for seasickness in the form of an oral tablet of meclizine (Pestafen®). This treatment was perceived as being ineffective, possibly due to the slow onset of action of this drug, and to the early incidence of vomiting preventing absorption of the drug.

3.1.4 Ocean Odyssey

The Ocean Odyssey accident involved an explosion and uncontrollable fire on the semi-submersible drilling rig. Of the 67 personnel on board, 58 escaped by TEMPSC, 8 jumped into the sea and one died on the rig. Weather conditions were relatively good (seas of 1 m). Of 40 survivors from the TEMPSC who completed a questionnaire, 68% suffered from some degree of seasickness while in the TEMPSC, with further cases occurring once on board the standby vessel. Heat, fumes, apprehension and the nauseogenic effect of observing others vomiting were all given as factors contributing to the incidence if motion sickness.

Only 9 of the 40 respondents took medication for seasickness. The drugs used are not known, and it is impossible to deduce effectiveness with such a small sample.

3.1.5 Rowan Gorilla I

Twenty seven personnel evacuated the Rowan Gorilla jack-up rig when tow lines broke in heavy seas (12-15 m). All entered a TEMPSC, with 88% suffering from seasickness and 50% vomiting in the first hour. Rescue did not occur until some 22 hours later when conditions had moderated (seas of 3-5 m). By then the incidence of seasickness had decreased to 29%, although half at that time felt that they were sweating and dehydrated. Almost all had recovered sufficiently to report good motor ability, strength and mental attitude.

Medication for seasickness had been taken by 96% of the survivors at the time of evacuation, with a variety of treatments: dimenhydrinate (oral tablet and / or suppository), meclozine (oral tablet) and / or scopolamine (transdermal patch). It is possible that the transdermal and suppository treatments may have contributed to the improvement in the survivors well-being with time, along with the improving conditions and adaptation to the motion.

3.2 HABITABILITY TRIALS IN TEMPSC

A series of trials were recently carried out by RGIT Limited (formerly RGIT Survival Centre Ltd) on behalf of the UK Department of Energy, to investigate the survivability of TEMPSC (Light & Coleshaw, 1993). A range of factors were measured:

- Motion sickness questionnaire;
- Thermal comfort of the volunteers;
- Fluid loss from the body;
- Environmental conditions within the TEMPSC - air temperature, carbon dioxide levels, carbon monoxide levels;
- Ambient conditions - air temperature, water temperature.

Environmental conditions within the TEMPSC were measured in calm water, under a range of weather conditions and occupancy levels, demonstrating that high occupancy levels during warm summer months can result in ambient internal TEMPSC temperatures of over 30°C, high humidity and CO_2 levels of up to 3.6%.

A final trial was carried out at sea with a TEMPSC loaded to full capacity (n=42), air temperature of 17-18°C, water temperature of 13°C and winds of Beaufort Force 6-7. Volunteers were dressed in either coveralls, a breathable dry suit or a neoprene insulated immersion suit. Twenty of the forty one subjects (49%) reported some degree of motion sickness within 30 minutes of departure, ranging from 'unwell' to 'dreadful'. Twelve subjects (29%) vomited. When asked what factors may have caused the sickness, 21 responded, some giving more than one answer:

- TEMPSC motion - 11 responses
- Individual's movement - 1 response
- Heat - 11 responses
- Vibration - 2 responses
- Diesel fumes - 4 responses
- Others vomiting - 9 responses

Thus, heat and others vomiting were perceived as being the main causes of sickness other than the motion of the boat.

The effects of potential heat stress were further studied by assessing both thermal comfort and fluid loss. Fluid loss ranged from 0.3 kg for subjects wearing coveralls to 0.8 kg for subjects in the insulated suits. Many commented that they were sweating, while thermal comfort ratings increased from comfortably warm to much too warm in a sample of 19 subjects.

The results thus suggested that, under conditions such as these, dehydration and debilitation are potentially serious problems which warrant further attention. It was proposed that improved ventilation would assist in reducing heat stress, while rapidly acting medication was a necessity in the prophylaxis and treatment of seasickness when onset occurs within the first 30 minutes after exposure to motion.

Factors in the design of conventional TEMPSC which may contribute to the incidence of motion sickness were described in a recent paper by Landolt and Monaco (1992). Several main points were made:

- Poor visual reference due to a lack of windows results in the occupants sensing severe motion via their vestibular (balance) organs, while their eyes signal no motion at all in relation to the insides of the boat. However, the provision of windows might exacerbate the problem in severe seas where the horizon could not be seen and the motion of visible waves opposed the motion of the boat. This situation would then increase the sensory mismatch.

- It was recommended that seating should be improved to provide better head and body restraint, and to allow more occupants to face forwards.

It is interesting to note that the modern designs of freefall TEMPSC generally include such design features as moulded seats, four-point body harnesses and head restraints, and a recumbent position once the boat is in the water. The use of head restraint may be limited to mild to moderate conditions, with less benefit received when motion is severe (Johnson & Mayne, 1953).

The modern designs of freefall TEMPSC feature seats which all face in one direction, with the added advantage that the visibility of the remainder of the occupants is greatly restricted, thus reducing the problem of observing others as they vomit.

3.3 SEASICKNESS DURING IMMERSION

While hypothermia and drowning are generally given as the primary causes of death of immersion victims, little consideration is given to the fact that seasickness may often have been a contributory cause. However, anecdotal evidence does exist of the incidence of vomiting in immersion victims. Keatinge's (1965) account of the fire and evacuation of the ship Lakonia states that most of the dead victims picked up from the water had vomitus around their mouths, noses and ears.

Bohemier (1993) suggested that seasickness may be a contributory factor in death after aircraft ditching in cold water. Bohemier estimates that 30-40% of individuals undergoing realistic survival training at sea (Survival Systems, Canada) become totally incapacitated by seasickness and are unable, or do not want, to help themselves. As a result, a survey is currently being conducted in Canada to assess the incidence of seasickness in aircrew trainees carrying out survival training at sea. Even in the simulated waves of an environmental tank (RGIT Limited, UK) a proportion of trainees taking part in an abandonment scenario experience motion sickness during a period of less than 15 minutes in a liferaft.

While there is little evidence for vomiting being a primary cause of death, the risk of choking or inhalation of vomit must be high. This problem will be compounded by exposure to waves breaking over the face, and the inhalation or swallowing of sea water. Cold shock may initially impair the ability of the immersion victim to control his/her breathing. The wearing of a lifejacket is essential in the bid to prevent drowning, while a sprayhood is an important aid to prevent water washing over the face. However, an unavoidable disadvantage is that if a victim is vomiting, a bulky high buoyancy lifejacket will make it more difficult to turn away from the face-up position, thus increasing the risk of choking.

3.4 SUMMARY

In summary, several factors appear to be important in reducing the incidence of seasickness and providing the best means of treating seasickness following accidents offshore:

- The most serious incidence of seasickness occurs during the first 30-60 minutes of exposure necessitating a drug with rapid onset of action and suitable route of administration;
- Heat stress and dehydration may cause deterioration of TEMPSC occupants with time;
- Adaptation to motion and effective medication may result in improvements in occupant well-being and performance with time;
- Maintaining good communications between a TEMPSC and standby vessel such that assessments can be made of the health status of the occupants, and more importantly whether status is deteriorating or improving;
- Improved design of TEMPSC giving attention to seating position and restraint, visual cues and ventilation;
- Attention to the role of seasickness in the deterioration of immersion victims.

4. DRUG THERAPY

4.1 TYPES OF ANTI-EMETIC DRUG

Table 1 summarises the anti-emetic drugs used in the prophylaxis and treatment of motion sickness, their routes of administration and duration of action. These drugs vary in their mode of action, although many show anti-cholinergic activity. Acetylcholine underlies the neurotransmission of information relating to motion, acting on the central nervous system (CNS) pathways between the vestibular organs of balance and the 'vomiting centre' in the medulla (Parrott, 1989; Reason & Brand, 1975). It has been speculated (Kohl & Lewis, 1987) that the psychostimulant drugs such as amphetamine may exert more direct actions on dopamine receptors in the basal ganglia. Further research is ongoing to investigate other drug groups with peripheral modes of action, in the search for treatments with fewer side-effects.

4.1.1 Antimuscarinic drugs

Anti-muscarinic drugs (the belladonna alkaloids) have been used for a wide range of clinical uses. Their predominant effect is to inhibit the effects of the parasympathetic nervous system by antaginizing the muscarinic actions of the neurotransmitter acetylcholine. The belladonna alkaloids were among the first drugs to be used in the treatment of motion sickness. Within this group is the drug scopolamine, sometimes referred to as hyoscine.

Scopolamine hydromide is thought to be the most effective prophylactic agent for the prevention and treatment of motion sickness (Parrott, 1989). Scopolamine has a duration of drug action ranging from hours up to days, depending upon route of administration. While the main central effect of scopolamine is to reduce symptoms of motion sickness, peripheral effects are also seen. Scopolamine initiates a pattern of increased vagal tone and more normal, stable gastric myoelectric activity during rotational motion (Uijtdehaage et al, 1993).

Scopolamine is available in a number of preparations, as detailed below:

- Oral ingested tablet (0.3 mg; taken 30 minutes before start of exposure to motion, repeated every 6-8 hours if required)
- Buccal tablet (0.6 mg)
- Intramuscular injection (0.2 mg)
- Transdermal scopolamine patch (0.5 mg per 72 hours; apply 5-6 hours before exposure to motion; replace if necessary after 72 hours)

Minor side-effects with scopolamine are well documented. Dryness of the mouth is relatively common (Price et al, 1981; Parrott & Jones, 1985; Shupak et al, 1989; Wood et al, 1990) but not incapacitating. Drowsiness has been reported in some cases (Price et al, 1981; Wood et al, 1990), although this is commonly reported with placebo treatments also. Reports of blurred vision tend to be more frequent than with a placebo, although the increased incidence is not generally found to be significant (Parrott & Jones, 1985; Attias et al, 1987; Wood et al, 1990). Skin irritations and contact dermatitis caused by the patches have been reported during long-term use (How et al, 1988; Shupak et al, 1989), and indicate that alternative treatments should be used for susceptible individuals.

Only rare cases have been recorded of withdrawal syndrome and toxicity following use of transdermal scopolamine, usually in the older age group. Symptoms include nausea, dizziness, low blood pressure and disorientation (Saxena & Saxena, 1990; Whiteman, 1990), while hallucinations have also been reported during patch use (Ziskind, 1988).

4.1.2 Antihistamines

Antihistamines (H_1 blockers) are known to act at therapeutic doses by depressing the central nervous system (CNS), which accounts for their usefulness in the prophylaxis and treatment of motion sickness. It also results in the common side-effect that they have sedative properties resulting in drowsiness in some subjects. The anti-cholinergic activity of most antihistamines accounts for another side-effect, namely, dryness of the mouth.

The main side-effects of dimenhydrinate is thought to be drowsiness, as demonstrated by Price et al (1981) during a sea trial of the drug.

Promethazine is said to have strong sedative effects. Wood et al (1992) showed an increased incidence of dry mouth, dizziness and drowsiness compared to placebo. When used to treat space motion sickness in the Space Shuttle, promethazine was administered in the pre-sleep period to facilitate crew rest (Davis et al, 1993), thus making use of its sedative properties.

TABLE 1
Summary of drugs used in the treatment of motion sickness

DRUG GROUP	DRUG Non proprietary name	Trade name	ROUTE OF ADMINISTRATION	ONSET	DURATION OF ACTION
Antimuscarinic	Scopolamine hydrobromide	Kwells®	Oral	30 min	4 hr
			Buccal	30 min	4 hr
		Scopoderm TTS®	Transdermal	6-8 hr	72 hr
			Injection	15 min	4-5 hr
Antihistamines	Cinnarizine	Stugeron®	Oral tablet	4 hr	8 hr
	Cyclizine	Valoid®	Oral tablet	2 hr	12 hr
	Dimenhydrinate	Dramamine®	Oral tablet	2 hr	8 hr
	Promethazine theoclate	Avomine®	Oral tablet	2 hr	24 hr
	Promethazine hydrochloride		Injection	15 min	12-18 hr
	Meclizine	Pestafen®	Oral tablet		

4.2 DRUG EFFICACY

4.2.1 Intramuscular injections

The intramuscular (IM) injection method of drug delivery provides a rapid and effective means of administering anti-emetics. Onset of action is generally within 15 minutes. Symptoms of vomiting are reduced to mild nausea after 1 hour, while peak excretion rates are reached two hours after injection of scopolamine hydrobromide (Price et al, 1981).

In a laboratory study using a rotating chair to produce motion sickness (Wood et al, 1992), both promethazine and scopolamine given by the intramuscular route were shown to be effective in increasing the number of tolerated head movements. Promethazine (25 mg) showed peak effectiveness 2 hours after injection and a duration of 12 hours. Scopolamine (0.2 mg) showed peak effectiveness 45 minutes after injection, with a duration of 5 hours. Scopolamine was found to be eight times as potent by the intramuscular injection route compared to the equivalent dose given by the oral route. This difference between the parenteral and oral routes of administration is thought to be due to the fact that drugs given by IM injection avoid the intestinal and hepatic circulations and thus avoid first-pass metabolism by the liver. IM promethazine showed twice the potency of the oral tablet, but a much longer duration of action. The differences in the potencies and duration of the two drugs may be accounted for by the high level of binding to tissue and plasma proteins by promethazine.

The efficacy of various anti-emetic injections has been investigated to assess the treatment of existing nausea and vomiting in pilots (Graybiel & Lackner, 1987) during a series of parabolic flights. Dramamine (50 mg) was found to give little benefit, scopolamine (0.4 and 0.5 mg) provided relief in 72% of cases, promethazine (50 mg) provided relief of symptoms in 78% of cases, while promethazine (25 mg) was ineffective. In cases where the drug injections were effective, relief of the symptoms occurred within 10 min, suggesting that anti-emetic injections can be used as a treatment for motion sickness rather than prophylaxis only.

Intramuscular promethazine (25-50 mg, adjusted for body weight) has also been successfully used to treat space motion sickness (Davis et al, 1993) in the crews manning the Space Shuttle. Symptoms of motion sickness were reduced within 1-2 hours in 90% of those treated. However, this was not a double-blind trial, with injections given on request. Levels of protection are thus uncertain.

Although of limited potential to the occupants of TEMPSC, an opioid agent (nalbuphine, 10 mg IM injection) has been investigated as a possible new treatment for motion sickness during space flight (Kohl & MacDonald, 1991). Such agents may potentially act directly at receptor sites in the vomiting centre, reducing the risk of potential unwanted side-effects.

The parenteral, intramuscular route of administration thus offers a means of providing rapid treatment of motion sickness. However, its use is currently limited to situations where a physician is available to administer the drug, and where conditions allow a sterile technique to be used to limit the chances of infection. Landolt and Monaco (1989) discuss the possibilities of using self-injection techniques. Auto-injectors have been developed for military use to administer anti-dotes to chemical agents. It is suggested that such devices could be adapted for use in the emergency situation offshore, and means considered for self-administration of anti-emetics directly through the fabric of an immersion suit. However, while such a suggestion is valid for a highly trained population such as the military, it is difficult to envisage such specialist first aid training being a cost-effective option for the average offshore worker. It could however be an

option to train and keep the rig medic supplied with injectable preparations, for situations where time was spent in the temporary safe refuge prior to evacuation.

4.2.2 Buccal and orally ingested preparations

The administration of an anti-emetic drug by mouth has the advantage that it is quick and simple. Each individual to be exposed to motion can be given a number of tablets, and with simple instructions, they can be self-administered. However, oral dosing while ill is thought to be questionable if vomiting results in rapid ejection of the tablet. Further, it has been argued (Norfleet et al, 1992) that oral administration of any drug will have limited usefulness as a treatment for motion sickness because gut motility is reduced when ill (Thornton et al, 1987; Wood et al, 1987).

The use of buccal delivery provides a painless and simple route of administration, with direct and rapid absorption of the drug through the oral mucosa. The effectiveness of buccal scopolamine was studied as a treatment for motion sickness (space sickness) during a series of parabolic flights (Norfleet et al, 1992). When compared to placebo, buccal scopolamine resulted in a significantly lower scores for nausea and a 50% reduction in the number of parabolas with vomiting. As the drug was administered after the fifth parabola, when nausea was already present, the drug appears to have acted as a treatment rather than providing prophylaxis. This supports a role for treating ongoing motion sickness.

When oral and buccal routes of administration of scopolamine hydrobromide were compared, no significant difference was found in the mean rate of absorption or the time to reach maximum plasma levels (Golding et al, 1991), although it should be born in mind that sampling of plasma took place every 15 min. The time for the buccal tablets to dissolve in the mouth was only 7.2 $\pm$ 3.8 min, with maximum plasma levels being reached after 47.9 $\pm$ 16.7 min. A correlation was found between the time for the tablet to dissolve in the mouth and the time to reach a maximum plasma level. Oral ingested tablets of scopolamine resulted in maximum plasma levels being reached after 60 $\pm$ 36.1 min, but there was much greater variability between individuals; in one subject, plasma levels were still undetectable after 3 hours, suggesting that this subject would have no protection from motion sickness. This variability may be due to the site of absorption, with food in the stomach potentially slowing down rate of absorption. The authors suggest that on this basis, buccal tablets may have a practical advantage, providing more consistent motion sickness protection.

In a search for a drug without the central side-effects associated with anti-muscarinic drugs and most antihistamines, a peripherally acting medication, flunarizine, was investigated. Flunarizine is a calcium antagonist which is effective in reducing vertigo in patients with vestibular disorders. When given to volunteers exposed to rotational motion on a disorientation trainer (Lee et al, 1986), flunarizine (30 mg) resulted in a significant reduction in the duration of nystagmus. The treatment was effective at 2 hours, with maximum effect at 8 hours. The effectiveness of flunarizine was only assessed in the laboratory, although the results suggest potential for use in the treatment of motion sickness.

More recently, the antihistamine terfenidine has received attention as a possible long-acting prophylactic agent for motion sickness. Terfenidine, unlike the antihistamines classically used as anti-emetics, does not readily cross the blood-brain barrier and therefore does not have the central side-effects common to the other agents. So far, a large single oral dose of terfenadine (300 mg) has been shown to significantly increase the number of head movements which can be tolerated before experiencing severe nausea (Kohl et al, 1991). Further studies are planned to assess the efficacy of a normal (60-120 mg) oral dose of terfenadine.

Overall, oral administration offers an effective means of providing prophylaxis for motion sickness, where the individual has time to prepare prior to exposure.

4.2.3 Transdermal patches

Scopolamine is the only anti-emetic drug treatment currently available in the form of a transdermal patch (section 4.1.1 refers). The transdermal therapeutic system for scopolamine (TTSS) provides a means of delivering a controlled dose of the drug to the circulation over a 72 hour period. The system is based on a small patch placed on the skin behind the ear. The patch consists of four layers; a backing layer, a drug reservoir containing 1.5 mg scopolamine, a rate-limiting membrane, and an adhesive layer containing a priming dose of 0.2 mg scopolamine.

Transdermal scopolamine provides a similar level of motion sickness protection to that provided by oral scopolamine (Parrott, 1989; Anon, 1989). Excretion rates of transdermal scopolamine are variable (Graybiel et al, 1976; Pyykko et al, 1985) suggesting that the actual rate of drug delivery varies considerably between subjects. This may account for some of the differences in the efficacy of the drug between individuals. Maximum mean excretion rates are reached after 10 hours, rates then declining slowly, but still being significant after 72 hours (Price et al, 1981).

When investigated as a treatment for post-operative sickness, transdermal scopolamine was found to be ineffective (Tigerstedt et al, 1988), emphasising the specificity of drug actions.

4.3 PERFORMANCE EFFECTS

The effects of anti-emetics on human performance have been studied in great detail due to the need for medications suitable for use in space flight and by pilots exposed to high gravitational forces. While the maintenance of high performance levels in the occupants of TEMPSC is not a priority, it is important that the coxswain should not be adversely affected by any drug treatment.

The side-effects of scopolamine are rather similar to some of the symptoms of motion sickness. As a result, oral scopolamine has been shown to have an additive effect on the secondary symptoms of motion sickness (Wood et al, 1990), increasing the incidence of drowsiness, dizziness, dry mouth and blurred vision over and above levels observed in the placebo group. These are all factors which could impair the performance of personnel.

To improve performance levels during periods of drug treatment for motion sickness, psychostimulants have been used alone and in combination with anti-emetic medications. Proficiency scores on a pursuit meter task were improved by combinations of promethazine and scopolamine with d-amphetamine (Wood et al, 1985), whereas the anti-emetics administered alone resulted in decrements in performance. Ephedrine was effective in reducing drowsiness and dizziness (Wood et al, 1990) during rotational motion. In a later study (Wood et al, 1992), intramuscular injections of scopolamine and promethazine both resulted in increased pursuit meter error scores, but the combination of promethazine (25 mg) plus d-amphetamine (10 mg) resulted in no increase in errors. A combination of promethazine plus d-amphetamine (Schroeder et al, 1985) has been shown to improve dynamic tracking performance. A drug combination of either scopolamine plus amphetamine or promethazine plus amphetamine is thus suggested for treatment of motion sickness where high levels of performance are required.

The CNS effects of scopolamine have been shown to impair memory for new information, impair attention and reduce alertness (Parrott, 1989). However, in a 3 year study of naval crew members using TTSS at sea (Shupak et al, 1989), self-estimated performance was significantly improved from 25 ± 2 % before treatment to 66 ± 3% using TTSS (performance was evaluated as the individual's ability to carry out his duties as a crew member at sea on a scale from 0% to 100%). This apparent difference in performance effects between the laboratory and the real environment emphasises the need for field and sea trials.

4.4 DRUG TRIALS AT SEA

While much valuable work has been carried out in the laboratory, true efficacy can only be assessed in the environment for which the drugs are targeted. Of the treatments specific to seasickness, the drugs which have received most attention are scopolamine, cinnarizine and dimenhydrinate.

The efficacy of oral scopolamine has been demonstrated in numerous trials at sea, dating back many years (Holling et al, 1944; Hill & Guest, 1945; Tyler, 1946; Glaser & Hervey, 1951). It is only relatively recently that scopolamine has been shown to have a higher therapeutic value when absorbed through the skin from a transdermal patch (Graybiel et al, 1976). These patches have the added advantage for extended sea voyages that their duration of action is designed to be 72 hours.

In 1981, Price et al examined the efficacy and side effects of transdermal scopolamine compared to dimenhydrinate and a transdermal placebo in sea trials conducted in a 60 ft, 70 ton yacht. Sea conditions ranged from a calm sea with 2 ft swell to 5 ft seas with 5 ft swell. Subjects feeling unwell were allowed additional medication on request in the form of an intramuscular injection of scopolamine hydromide. The transdermal scopolamine was shown to provide the highest level of protection with the only significant unpleasant side-effect being a dry mouth. Administration of transdermal scopolamine 16 hours before motion was more effective than administration only 4 hours before motion. Dimenhydrinate provided a lower level of seasickness protection associated with a 50% incidence of drowsiness.

In a later study (Levy & Rapaport, 1985), the relationship between the efficacy of TTSS and time of application prior to motion was investigated by comparing the response of subjects who took the medication 8 hours or more before the sea trial, and those who disregarded instructions and took the medication less than 4 hours prior to departure. Seventeen men and 27 women were exposed to two 4-hour cruises in a large sailing yacht, each experiencing seas with 2 to 5 foot swells. Of those who applied the patch 4 hours or less before motion (n=12), 50% experienced severe motion sickness (moderate nausea or vomiting), while of those subjects who applied the patch 8 hours or more before departure (n=32), only 2% experienced severe symptoms. Whilst the size of the sample was rather small, the difference in response was none the less marked. No significant difference was found in the incidence of motion sickness experienced by the men (41%) compared with the women (44%).

In a study of the long-term efficacy of the treatment at sea (Attias et al, 1987), TTSS was administered to 38 naval volunteers, 5 hours prior to departure, for a 3-day cruise in a 3000 ton vessel. Sea states ranged from Beaufort Force 3 on Day 1, Force 2-3 on Day 2 and Force 2-3 on Day 3. When compared to placebo transdermal patches, the TTSS provided 74% protection from severe nausea and vomiting on Day 1. The level of protection had fallen to 39% by Day 3, thought to be due to adaptation to motion occurring in the placebo group. The incidence of headache, dry mouth and blurred vision were somewhat higher in the TTSS group, while drowsiness and apathy was

observed more in the placebo group. It should be noted that there are certain similarities in the side-effects of anti-emetics and motion sickness.

A much more comprehensive study of the long-term effects of TTSS at sea was carried out on 122 volunteers from the Singapore Navy (How et al, 1988). The subjects, aged 19-45 years, spent 18 days at sea in a 2,490 ton vessel, during the monsoon season. The first nine days were spent in open water with sea states of Beaufort Force 1-4, while the second nine days were spent in coastal waters and sea states of Beaufort Force 1-2. Seasickness experienced during the previous 24 hours was recorded each day on a visual analogue scale. A profile was established for the normal responses to motion without medication: severe seasickness soon after putting to sea, rapid improvement over the next few days, with a fluctuating baseline after Day 5 which closely correlated with sea state. The inexperienced seamen suffered more initial symptoms, but showed no significant differences in response later in the trip. TTSS reduced symptoms significantly over the entire period at sea. The protection rate provided by transdermal scopolamine ranged from 46-57%, with greatest protection during the first 9-day period. The effect of TTSS was greatest when seasickness was most severe: before adaptation could occur; amongst the inexperienced seamen; and during episodes with the highest sea states. In calm seas the patches provided little benefit, such that the side-effects then constituted a minor disadvantage: 6 cases of mild skin irritation, 2 cases of moderate skin irritation, 1 case of vertigo and 3 cases of difficulty in focusing. (It should be noted that the total number of unwanted effects was the same for placebo and scopolamine patches). The authors concluded that 'Scopoderm® is a useful preparation in preventing (or minimising) seasickness in monsoon seas'.

The prevalence of unwanted side-effects during good weather at sea had previously been investigated in a study of psychological test performance at sea (Parrott & Jones, 1985). Choice reaction times and code substitution performance levels were not significantly changed. Letter cancellation errors were more frequent following scopolamine compared to placebo, while 5 subjects were unable to carry out the test due to inability to focus. This effect would appear to only affect susceptible individuals as the incidence of blurred vision was similar in TTSS and placebo groups. While drowsiness has been shown with land trials of oral scopolamine, there was no evidence of TTSS altering levels of alertness at sea.

Ginger root has been investigated as an alternative treatment for seasickness, without significant success. Naval cadets who took 1 g of powdered rhizome of ginger reported fewer symptoms of nausea and vertigo, but the difference was not statistically significant (Grontved et al, 1988). Anecdotal reports of the effectiveness of ginger may be explained, not by any action on the vestibular system, but by the influence of the ginger root agents on the gastric system (Holtmann et al, 1989).

5. OTHER PREVENTIVE MEASURES

5.1 ACUPRESSURE

'Alternative medicine' has also been investigated in relation to the prevention of motion sickness. Acupuncture has been used to control nausea and vomiting, with stimulation of the P6 or Nei Kuan acupuncture point, and reputedly, by rubbing or pressing the right wrist.

Bruce et al (1990), investigated the effectiveness of the Sea Band®, marketed for the prevention of seasickness. In a laboratory study using fairly severe rotational motion, the acupressure band did not provide significant protection compared to a placebo band. However, the authors note that only a proportion of the population are thought to derive benefit from acupuncture, while it may be that wrist movement is necessary to produce a massaging effect by the band. A very similar study comparing bands placed either correctly or incorrectly on the wrist produced a similar negative result (Warwick-Evans et al, 1991).

It has been suggested that some benefit is provided by the self-administration of transcutaneous electrical nerve stimulation (Stott, 1991) to the Nei Kuan acupuncture point. However, despite comparison with placebo treatments, the placebo effect cannot be ruled out as it is not possible to mask the perception of electrical stimulation. Whilst effective acupressure would be an option for offshore use, electrical stimulation obviously is not, although such research may increase our understanding of acupressure techniques.

5.2 ADAPTATION

In the absence of treatment, adaptation to the effects of motion will occur, although variability between individuals is large. The Singapore Navy study (How et al, 1988) demonstrated a gradual fall in the incidence of motion sickness in the untreated group, with incidence of vomiting minimal after 4 days at sea and slight nausea adapting over a 10-day period. Incidence of seasickness was lower in the group of experienced sailors compared to their inexperienced colleagues, suggesting a long-term adaptive process, although some degree of self-selection might be expected.

It has been suggested (Parrott, 1989; Stott, 1991) that the use of transdermal scopolamine may delay the development of adaptation to motion sickness. Whilst the treatment facilitates adaptation over the 3 days on which the drug is taken, removal of the transdermal patch may result in a higher incidence of seasickness compared to untreated individuals (Van Marion et al, 1985; Wood et al, 1986).

In two of the offshore accidents discussed previously, the Vinland and Rowan Gorilla accidents, incidence of severe nausea and vomiting had decreased by the time the occupants were rescued. This may reflect both the improvement in weather and sea conditions, and the early stages of adaptation to the motion stimulus.

Whilst airforces use the adaptation process during training in an airsickness de-sensitisation programme (Banks et al, 1992), this type of preventative measure is only really suitable for individuals who will be exposed to motion on a regular basis. However, the Canadian offshore industry do follow a procedure of exposing all personnel to motion at sea during their survival training. The objective is to build

confidence in students that they can survive a period of severe seasickness. While this single exposure will not bring about adaptation, the process of improving individuals coping skills is fundamental to survival training. In the UK, only coxswains spend sufficient time in a TEMPSC at sea, during training, to develop any degree of adaptation to motion. Again, self-selection is more likely to confer some protection to these individuals.

6. CONCLUSIONS

The emergency evacuation of an offshore structure requires rapid reactions and gives little time for preparation. In order to provide adequate prophylaxis and treatment of seasickness during evacuation, escape and rescue, an anti-emetic drug must have the following properties: it must be easy to administer; it must have a rapid (< 30 minutes) onset of action; a duration of action of several hours or more; and minimal side-effects.

A number of main conclusions can be drawn from this review of the recent literature:

- Scopolamine is thought to be the most effective prophylactic agent, both for the prophylaxis and treatment of motion sickness.

- Use of parenteral (intramuscular) injection is attractive due to the very rapid onset of drug action by this route. However, this method requires a high level of training for effective use offshore. The rig medic and advanced first aiders are the only personnel likely to take on responsibility for the injection of drugs.

- Oral tablets offer a simple and easy method of administration. Buccal preparations are preferable, as the drug is rapidly absorbed through the oral mucosa, reducing the time period when vomiting might cause ejection of the tablet. Buccal tablets have also been shown to provide more consistent efficacy compared to ingested tablets which must pass through the stomach. Tablets should be kept, not only at muster points and in the TEMPSC, but also in with the offshore worker's personal issue of equipment. This would allow medication to be taken at the earliest possible time, before the donning of clumsy gloves.

- Transdermal patches provide an effective means of administering a therapeutic dose of drug over a long period. The major disadvantage in the present context is the slow onset of action (6-8 hours), meaning that the patches cannot be used prophylactically. However, patches could be applied to provide a continuous regime of treatment, both while awaiting rescue and once transferred, perhaps to a standby vessel where exposure to motion may continue.

When considering medications currently available in the UK then the most effective treatment regime would appear to be the administration of a buccal dose of scopolamine at the earliest possible time, with a transdermal scopolamine patch applied as a back-up dose. In situations where a medic is available, and time allows, then intramuscular injections may be considered.

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GLOSSARY

Anti-emetic drug	A agent used to prevent or alleviate vomiting and nausea.
Anti-histamine	A drug that counteracts the effect of histamine.
Anti-muscarinic drug	An agent used to block the transmission of nerve impulses in the parasympathetic nervous system.
Efficacy	The ability of a drug to produce the desired result.
Emetic	A substance that induces vomiting
Placebo	An inert substance, such as the sugar, lactose, which is used as a sham drug. The placebo has no inherent pharmacological activity but may produce a response by the suggestion attendant upon its administration.
Prophylaxis	A treatment given to prevent the development of symptoms, administered prior to exposure to a given stimulus (eg. motion).

$$\text{Protection Index (\%)} = \frac{\text{(\% sick in the placebo group - \% sick in the treatment group)}}{\text{(\% sick in the placebo group)}}$$

Side-effect	An effect other than that for which any given drug is administered.

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